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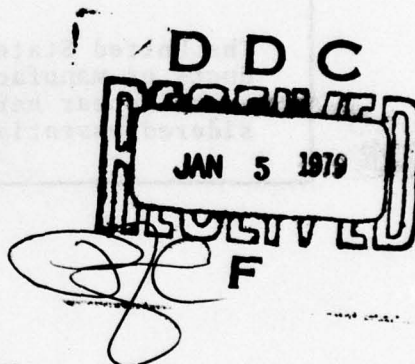
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THE AIRPORT NETWORK FLOW SIMULATOR

Juan F. Bellantoni

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMININISTRATION
Transportation Systems Center
Cambridge MA   02142

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16. Abstract

The Airport Network Flow Simulator is a FORTRAN IV simulation of the flow of air traffic in the nation's 600 commerical airports. It calculates for any group of selected airports: (a) the landing and take-off (Type A) delays; and (b) the gate departure latenesses (Type B delays) at the selected airports and at all other airports to which these delays propagate by means of scheduled commercial flights. The airports are selected by the user who must input hourly aircraft processing rates for each airport selected. The cost in lost passenger time and aircraft operating expense is also calculated.

A validation process was applied to the simulator, using field data gathered from two air carriers, a large U.S. trunk line carrier and a local service carrier. Results are also reported for sensitivity analysis of the simulated B-delay to slack in gate departure schedules.

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PREFACE

The Airport Network Flow Simulator (ANFS) described in this report is a computer simulation of the propagation of delays through the network of U.S. commercial airports. It was developed for the Federal Aviation Administration, Office of Aviation System Plans, to help it assess the benefits of investments in airport capacity made under the 1976 Amendments to the Airport and Airway Development Act (P.L. 94-353). The outputs of the ANFS, along with that of the Airport Performance Model,[1] a single-airport simulation, will be employed to produce an airport investment handbook for the use of the FAA and of airport managers.

The simulator here described is the outgrowth of previous efforts[2] carried out by the Transportation Systems Center for the Office of Aviation System Plans. The data for validation of the ANFS were gathered and interpreted by Simat, Helliesen and Eichner, Inc. Newton Centre, MA, under contract DOT-TSC-1184.

The validation data were analyzed by Dr. Joseph A. Tanne of Kentron International, Inc., who also devised the linkage algorithm and constructed the Demand Data file of Section 2.1 of this report.

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[1] Hiatt, D., S. Gordon, and J. Oiesen, "The Airport Performance Model," Report No. FAA-ASP-75-5, U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA, April 1976.

[2] Gordon, S., "The Airport Network Flow Simulator," Report No. FAA-ASP-75-6, U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA, May 1976.

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1. INTRODUCTION

The scheduled air transportation network in the United States comprises over 600 airports and more then 5,000 aircraft. These aircraft make about 20,000 flight legs in a typical day of scheduled service, or an average of about four flight legs per vehicle per day. As a result, the country's commercial airports are interrelated by the flow of traffic. Congestion at one airport will affect other airports to which flights are destined from the congested airport. At least two effects may be distinguished:

(1) Modification of arrival demand at the down-line airports. If flights are delayed in taking off at a congested airport, they may arrive late at their destination, thereby shifting the demand for landing service at the destination airport.

(2) Gate departure delays at the congested and down-line airports. If arrival delays are great enough at a congested airport, the vehicle will be unable to meet its scheduled gate departure time at that airport and, possibly, at succeeding airports in its intinerary.

The first of these effects will modify the demands made upon the down-line ATC terminal facilities as a function of time. The consequent peaking or/and smoothing of the arrival demand profile is of primary interest to the Local and Central Flow Control facilities in the ATC System.

The second of these effects is the major subject of this report. The purpose of the Airport Network Flow Simulator (ANFS) is to model (1) the effect of airport capacity on take-off and landing delays and, (2) the subsequent propagation of those delays as departure latenesses through the air transportation network. The simulation is expected to be of use in evaluating the economic benefits of airport capacity improvement because reducing delays at a major airport can be expected to reduce gate departure delays at downline airports, with consequent saving in passenger waiting

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time. Preliminary field data, discussed in Appendix A and in the
section on validation, suggest that gate departure delays (in air-
craft-minutes) can be more than one third of the system-wide take-
off and landing delays on an eventful winter day. The correspond-
ing economic losses may reach 25% of the take-off and landing
delays. These data indicate, therefore, that a complete benefit/
cost analysis of airport capacity improvement should take into
account the gate departure latenesses caused by landing and take-
off delays. This is what is what done in the ANFS.

A third network effect of airport congestion is that of in-
creased slack time in air carrier schedules. In general, slack
ground time built into the arrival and departure schedules of an
aircraft will absorb arrival lateness, if any, and prevent it from
becoming gate departure lateness. Since ground slack time is
unproductive aircraft time it is an index of fleet utilization
efficiency, and is therefore related to fleet size. Although
ground slack time often serves purposes of scheduling other than
delay absorption, the trade-off between ground slack time and
network delay is still of interest. For this reason the ANFS
allows the user to adjust the ground slack time of all aircraft in
the commercial fleet and to calculate the corresponding network
delays.

A fourth network effect, not computed by the ANFS, is that of
gate arrival latenesses and their effect on missed passenger
connections. This is not computed in the ANFS because of the
uncertainties in modelling passenger connection times. (They vary
from airport to airport, and little data are available.) Another
difficulty is that of establishing the cost of missed connections.
Nevertheless, it may be possible to incorporate a crude gate arrival
lateness economic model into subsequent versions of the ANFS.

1.1 TERMINOLOGY

In order to facilitate discussion an abbreviated terminology will be used throughout this report.[*]

Delays in aircraft operations such as in landing, take-off, turn around and enroute flight will be referred to as A-type delays. Latenesses in meeting arrival and departure schedules will be termed B-type delays. B-delays are a measure of schedule conformity. Our major interest in this report is in landing and take off types of A-delay, and in the consequent gate departure lateness at originating and down-line stations, which are forms of B-delay.

1.2 SCOPE OF THE AIRPORT NETWORK FLOW SIMULATOR

Although the majority of landing and take-off delays are believed** to occur at fewer than ten major airports, little is known about the geographic distribution of the resultant B-delays. In order to explore this distribution, and in order to encompass the entire B-delay effect, the ANFS has been structured to include all airports in the contiguous 48 states receiving commercial service in February 1976, plus selected airports in Canada, Hawaii, Alaska, and Puerto Rico. A total of 665 airports is included in the data base (See Section 2.1). The traffic data base is all scheduled commercial traffic at these airports for a single day, Feb. 16, 1976. This day was selected for validation purposes, but the data base may be regenerated for other days.

Military, general aviation, and non-scheduled commercial flights are not incorporated into the traffic data base, but their effect on runway availability for scheduled flights is allowed for.

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[*] The terminology here introduced is a slight modification of that first employed by Gordon (Reference (1))

** See Reference (2), p 37.

A-delay is calculated by a first-come-first-served, single runway airport model, using hourly processing rates specified by the user. Delay propagation is based on fixed flight times, and ground service times that were derived from an analysis of airline schedules in the data base. The gate servicing queues are not modelled.

The traffic data base on which the simulation is based is described in Section 2. The other input data to the simulation, dealing with capacity and cost, are also described in Section 2.

The simulation itself is described in Section 3 and its output is described in Section 4.

In order to obtain an estimate of the accuracy of the simulation, data were gathered from two trunk lines and one local service carrier. Both the data base and the delay output of the simulator were compared to these field data, and the results are described in Section 5.

The Appendices give a summary of the contractor's analysis of the field data he gathered on B-delays; a set of program listings; and a guide to the use of the ANFS program.

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2. INPUT DATA

The input data required by the ANFS is of three types: demand, capacity and cost. By far the most extensive of these is the demand data, since it encompasses all scheduled domestic flights for an entire day. This demand data base is too large to be supplied by the user, and hence is provided as a separate, computer generated disk file. The capacity data, in contrast, is well within the capability and interest of the user to supply. On any given day serious capacity problems occurring at relatively few airports can cause extensive delays throughout the air network. Hence the user has been given the option of specifying the hourly capacity at up to 32 airports of his choice. Finally, the load factors and cost coefficients for passenger time and aircraft operation have been pre-calculated and stored on disk for input to the ANFS. These data are not too extensive to be modified by hand if the user so desires.

The following three sections describe the demand, capacity and cost input data bases.

2.1 DEMAND DATA

Demand is specified in the file ANFS.DAT as a set of scheduled aircraft itineraries. The file also includes a list of airports (3-letter codes) covered by the itineraries and their time zones. The exact form of the demand file is given in Table 2.1. In this file an event is defined as a gate arrival or gate departure. For each such event the last four items LM, TS, TAU, CECODE of Table 2.1 are recorded in the file. All the events scheduled for a single aircraft in a selected day are grouped together in the file, in order of increasing TS, and constitute the itinerary of the aircraft. Itineraries are strung one after another in the file, the total number of events in all itineraries being NEVNTS.

Each itinerary has the same structure. The first event in the itinerary (K odd) is the aircraft's first scheduled gate departure of the day, which starts at 10:00 GMT (5:00 AM EST).

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TABLE 2.1 FORM OF THE DEMAND FILES

NAME	DEFINITION	FORMAT	NUMBER OF ITEMS
NAPTS	Number of airports covered	I10	1
APT(J)	3-letter code of Jth airport	20A4	J=1, NAPTS
ZONE(J)	Time zone for J^{th} airport	20I4	J=1, NAPTS
NACFT	Number of itineraries	\} 2I10	1
NEVNTS	Number of events		1
LM(K)	Airport number of Kth event	\} I3,3I6	K=1, NEVNTS
TS(K)	Scheduled time of Kth event		
TAU(K)	Minimum time between K^{th} and $(K+1)^{th}$ event		
CECODE(K)	Carrier and equipment code for K^{th} event		

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It occurs at airport number LM(K) of the APT list. TAU(K) gives the minimum normal interval to the next event, K even, which is gate arrival. This interval includes taxi time from departure gate to runway, takeoff, flight time to arrival runway, and taxi time to arrival gate. (The method of obtaining TAU is described in Section 2.1.3.)

The 5 digit code word CECODE gives the carrier number in its three most significant digits and the equipment type number in its least significant two digits. For gate arrival events (K even) TS, LM and CECODE have the same meanings as for departure for the given equipment type. (Again, Section 2.1.3 describes the method of obtaining TAU.) The itinerary continues with similar event pairs (K odd, K even), until the aircraft's final gate arrival of the day, which is indicated by TAU equal to 43201. Itineraries need not be arranged in any particular order in the file.

As an example, a printout of the first part of the ANFS.DAT file is given in Appendix B.1. This particular file, it will be observed, covers 665 airports, which are all airports in the contiguous 48 states that received scheduled carrier service on February 16, 1976, plus YUL, YYZ, ADQ, ENA, AKN, JNU, FAI, ANC, HNL, SJU, and OUT. The last is a fictitious airport used to represent all airports not on the APT list. It will be seen also that there are 5,402 aircraft itineraries and a total of 38,222 events, representing 19,111 separate flight legs, in the file. Although the ANFS may run on the full ANFS.DAT file of 38,222 events, it is usually more economic to extract only a portion of the file for a particular segment of traffic, as will be described in Section 2.1.4.

The key to the construction of the demand file, and one of the critical factors in simulator accuracy, is the algorithm that links together the separate legs of the Official Airline Guide (OAG) to produce the complete airframe itineraries of ANFS.DAT. This algorithm is a refinement of that of Reference (4). Because of the importance of this algorithm, it is described fully in the next two sections.

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2.1.1 The Linkage Algorithm

In order to trace individual aircraft through a day's journey, an algorithm for linking incoming flights at a given airport with outgoing flights based on a first in-first out approach was employed. The basic assumption is that each airline would attempt to minimize the maximum ground time for its fleet of aircraft so that an outgoing flight at a given airport would utilize the previously arrived aircraft which had been on the ground longer than any other incoming aircraft of the same type available for the outgoing flight.

The actual linkage of incoming flights with outgoing flights at a given airport utilized OAG flight schedule data and was accomplished as follows: first, a listing of all incoming flights on a given day for a given airline and aircraft type at a given airport was constructed, the flights being listed in order of arrival time. This list was then compared with a corresponding list of all flights departing the given airport for the airline on that day with the same scheduled aircraft type, the flights in this list having been arranged in order of departure time. Inasmuch as Greenwich Mean Time (GMT) was used for the arrival and departure times, the times were arbitrarily ordered from 10:00 GMT to 9:59 GMT to cover a 24 hour time period commencing at 5:00 A.M. (local time) in New York.

All shuttle flights (indicated by a non-numeric character in the last digit of the flight number) were then deleted from the lists and the corresponding flight segments were considered to be unlinked flight legs at the given airport. Then all incoming and outgoing flight pairs with the same flight number were deleted from the lists and linked as long as the departure time for a given flight did not precede the arrival time for the incoming flight with the same flight number within the indicated 24 hour period.

Now the arrival and departure times for the remaining flights in the lists were compared. It was assumed that a given incoming aircraft, departing on a flight leg having a different flight

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number than the incoming flight, would spend at least 30 minutes on the ground. Thus, a minimum ground time adjustment factor of 30 minutes (40 minutes for DC10, L1011 and 747 type aircraft) was added to the arrival time of each incoming flight before the actual comparison of arrival and departure times. Starting with the first arrival time (i.e., the first arrival time after 10:00 GMT), the arrival times were compared in a one-to-one fashion with corresponding departure times until the end of the arrival list was reached, or until a departure-arrival time pair was found with the departure time preceding the arrival time or until the end of the departure list was reached.

If the end of the arrival time list was reached, with each arrival time preceding its corresponding departure time, then the given correspondence between arriving and departing flights was clearly on a first in first out basis, minimizing the maximum ground time for the given aircraft fleet, and the flights were linked as indicated.

If, however, a given departure time preceded its corresponding arrival time, then the arrival time was compared with succeeding departure times until a departure time was found which did not precede the arrival time. The given departure time was then put in correspondence with that arrival time and the next arrival time in the list was compared with the next departure time and the one-to-one correspondence was continued as long as each departure time did not precede its corresponding arrival time. This correspondence procedure was terminated when the end of either the arrival or departure time list was reached.

If the end of the departure time list was reached, and the last departure time preceded the arrival time it was being compared with, the given arrival time was made to correspond with the first departure time (implying a linkage of the arriving aircraft with a flight departing on the succeeding day).

The actual arrival-departure linkages were then constructed by starting with the last arrival-departure correspondence for which the arrival time succeeded the first departure time it was

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compared with (or for which the end of the departure list was reached and an arrival time was corresponded with the first departure time) and linking the incoming and outgoing flight legs in a one-to-one fashion. When the end of either list was encountered, the next flight leg was the first flight in the list. This procedure was continued until all the flights in either list were accounted for. If the lists were unequal in length (more incoming or outgoing flights), the remaining flight legs in the longer list were considered to be unlinked flight stages.

Thus, the linkage of incoming and outgoing flights by a comparison of arrival and departure times is basically a two-stage process. In the first stage a starting arrival flight and corresponding departure flight are determined. In the second stage the actual linkages are constructed by proceeding in a one to one matching of succeeding arrival and departure flights, cycling back to the beginning of a list when the last element is reached, and terminating the process when all the elements in the shorter list have been accounted for. In addition, inasmuch as it was desired to trace a given aircraft for only one day's itinerary, all linkages which would link an incoming flight to one departing on the next day (i.e., during the next 24 hour time period starting at 10:00 GMT) were not used, the corresponding incoming and outgoing flight stages being considered as unlinked at the given airport.

To illustrate the above procedure suppose we had the following flights for some airline arriving and departing an airport with a given aircraft type on a given day:

Flight #	Arr. Time	Dept. Time	Flight #
0050	10:20	10:30	0050
005*	11:00	12:00	0053
0054	11:20	12:30	0055
0055	13:00	14:00	0057
0056	13:20	14:30	006*
0058	16:00	15:00	0059
0060	16:20	16:30	0061

First of all, arriving flight 005* and departing flight 006*
(shuttle flights) would be eliminated from their respective lists
and these flight stages would be considered unlinked flight seg-
ments. Then arriving flight 0050 would be linked with departing
flight 0050 and arriving and departing flights numbered 0055 would
be eliminated from the above lists and considered as unlinked
flight legs since the departure time precedes the arrival time.
The remaining flight segments are now:

Flight #	Arr. Time	Dept. Time	Flight #
0054	11:20	12:00	0053
0056	13:20	14:00	0057
0058	16:00	15:00	0059
0060	16:20	16:30	0061

Arriving flight 0054 would now be made to correspond with departing
flight 0053, flight 0056 with flight 0057, but flight 0058 would
not be put in correspondence with flight 0059 since the departure
time for flight 0059 precedes the arrival time for flight 0058.
Thus, flight 0058 would be compared with the next sequential
departing flight and would be paired with flight 0061 since the
departure time for flight 0061 does not precede the arrival time
for flight 0058. Since the end of the departure list has now
been reached flight 0060 is joined with flight 0053 and the flight
stages are linked in a one-to-one sequential fashion starting with
the flight 0060 to 0053 linkage, resulting in the following set
of linkages.

Arr. Flight #	Dept. Flight #
0060	0053
0054	0057
0056	0059
0058	0061

Inasmuch as the first linkage of flight 0060 to flight 0053
implies a linkage of an arriving flight with one departing on the
following day, this linkage is deleted from the final list of
linked segments and these flight legs are considered as unlinked
segments.

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2.1.2 The Original Linkage Algorithm

The flight leg linkage algorithm described in the preceding discussion is a modified version of an algorithm documented on pages 7-9 of Ref. (4). The original algorithm did not omit shuttle flights from the linking prodedure and assumed that the number of arriving flights was equal to the number of departing flights. If there were more arriving or departing flights, the excess flights at the end of the longer list were deleted before the linkage procedure was initiated. In addition, the original algorithm did not delete linkages between arriving flights and flights departing on the next day.

The present algorithm was developed from the original one by a series of refinements, as described. Because of the importance of the linkage procedure to simulator accuracy, the effect of each refinement was checked against actual airframe linkages, with the results reported in Section 5.

2.1.3 Construction of the Complete Demand File ANFS.DAT

Given the individual linkages of flight legs, as obtained by the linkage algorithm, construction of the complete demand file ANFS.DAT was relatively straightforward.

First, complete itineraries were extracted by locating a departure flight leg that was not paired with any incoming flight leg at the airport. It was then traced to its destination airport where the outgoing leg to which it was linked (if any) was added to the itinerary. This process continued until no outgoing leg was available. The itinerary thus formed was removed from consideration and the process repeated until all flight legs had been placed in itineraries.

The completed itineraries were then put into the form described in Table 2.1. All the airports were numbered arbitrarily from 1 through NAPTS, thus providing the LM values for the itineraries. The TS values were taken directly from the itinerary data, in seconds GMT.

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The TAU values, however, were the result of a search process. The TAU value for a gate departure is intended to be the undelayed time from the gate departure to the following event, gate arrival at the end of the leg. The "undelayed" time varies with route chosen, takeoff runway, takeoff weight (which affects takeoff time), ascent time, and flight time, aircraft type and power setting, head/tail winds, approach route and taxi routing at both origin and destination airports. The scheduled block times given in the OAG allow for all these factors, on average, plus an average traffic delay expected on the given flight based on the airline's previous experience. Therefore OAG block times cannot be taken to be undelayed times. However, late night and early morning flights, for example, probably have little or no traffic delay built into their OAG shedules. It was assumed, therefore, that among all scheduled flights by a given aircraft type between two airports, at least one OAG block time is an "undelayed" time. This undelayed time would necessarily be the minimum of all similar times, and was searched out and entered as the TAU value for all flights by the given aircraft type between the two airports. The same process was employed to determine the gate turn-around time at an airport for a given aircraft type, which was entered as the TAU value for gate arrival events of the appropriate aircraft type and airport (except for the last TAU of each itinerary, which was coded as 43201, as described previously).

The carrier/equipment code, finally, was taken from the OAG information for the flight legs of the itinerary. The 2-letter carrier code was replaced by an assigned three digit number, multiplied by 100, and added to a two-digit number assigned to the aircraft type, the result being the five-digit CECODE entered with each event. Although the same carrier/equipment code applies to all events in an itinerary, it was entered repeatedly for each event in order to reduce simulation run time. The three-digit carrier code and two-digit equipment codes correspond to positions in the carrier list and equipment list in Appendix B-3, Cost Data Program.

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2.1.4 Extraction of the Demand File

The complete demand file ANFS.DAT fills over 150,000 36-bit words. In many applications one is concerned with the effect of only one airport on the rest of the system. Therefore only itineraries that contain that one airport need be retained in the data base. Accordingly, a short program was constructed to extract from ANFS.DAT only itineraries involving a single airport, which the user specifies. The resultant file(s), FLIGHT.DAT, are in exactly the same format as described above for the full demand file, but are substantially smaller. For example, the file result-ing when only ORD related traffic is extracted is about 21% of the full demand file. The extracted airport is the first one in the new APT and zone lists.

2.2 CAPACITY DATA

The airport capacity data, although available on disk, can be made up and entered via cards by the user. A sample input is shown in Appendix B-2. These data must be in the format of Table 2.2. The first card image contains four parameters needed to control the simulation and printout. The use of these control parameters is more conveniently discussed in Section 3. following. The next cards come in pairs, one pair being required for each airport the user wishes to specify, plus one pair for the airport ALL, which controls all airports in the demand data base not specified on the preceding cards. The user may input data for up to 32 airports, or for no airports at all, but must always provide for airport ALL at the end of the data set.

For each airport he selects, the user provides, on the first card, the airport three-letter code and the runway service inter-val, in seconds, for 24 hours commencing at 00:00 hour, local time, and ending at the 23:00 hour, local time. The runway service time is defined as the minimum allowable number of seconds between operations at the airport and is equal to 3600 divided by the airport processing rate in operations/hr. Although this minimum varies with aircraft type, arrival/departure mix, and other fac-tors, the ANFS can accomodate only a single number for any given hour. Hence the user must select the number carefully so as to

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TABLE 2.2 FORM OF CAPACITY DATA

Parameter Card (I8,10I6)

> EXPFAC   Traffic expansion factor (percent)
> PLEVEL   Printout delay level (aircraft-minutes)
> MAXGT   Maximum ground turn-around time (min)
> KSLACK   Ground time slack parameter (min)

For each of up to 32 airports, plus the airport "ALL"

CARD 1. (1X, A4, 24I3)

> APT   Airport 3-letter code
> SIG(I)   Runway service interval by local hour I,
>   I = 1, 24 (seconds)

CARD 2. (1X, I4, 24I3)

> KGA   Non-scheduled traffic as percent of all traffic
> GFAC(I) Percent of non-scheduled traffic occurring
>   in local hour I, I = 1, 24

be representative of the hour's aircraft type mix, arrival/departure ratio, and runway configuration(s).

On the second card for each airport the user provides the ratio of non-scheduled traffic to all traffic for the day, in percent, followed by the breakdown of non-scheduled traffic throughout the hours 00:00 -23:00 local time. This breakdown must be expressed as the percentage of the day's total non-scheduled traffic that occurs in each of the 24 hours. (As a check, the 24 hourly percentages should add to 100.)

For each airport specified, including all those covered under airport ALL, the ANFS will calculate the landing delays, take off delays, and gate departure delays (B-delays) by GMT hour. It will also calculate the B-delays at all airports, as well as the costs of passenger time and aircraft operating time for all delays. If the user is interested in the effect of capacity at only a few airports he should input the data for those airports, followed by the cards for airport ALL with 0 seconds service time in each hour. The program will then calculate the landing, take-off and B-delays at the specified airports, plus the B-delays produced in the rest of the system by the specified airports.

2.3 COST DATA

The cost coefficients and subsidiary data used by the simulator were generated by the FORTRAN program listed in Appendix B-3. The data stored in that program came from various sources, which will now be described.

The value of passenger time, PCOST, was taken to be $12.50/ hr, in conformity with general usage established by the Federal Aviation Administration.

Aircraft operating costs are of two types: take-off costs (TCOST) and landing costs (LCOST). Take-off costs are the fuel, crew and maintenance costs per hour incurred while waiting to take off after having left the gate. Landing costs are the same items with an adjustment for higher fuel consumption incurred during

landing delays. TCOST and LCOST are given as a function of aircraft type in Table 2.3, which was extracted from Appendix B.3. This Table also shows the 3-letter aircraft type designator AC3LC, which corresponds to those used in the Dec 1976 OAG. Types 1 through 57 are non-jet, types 60 through 85 are jets. The costs were based on the size/engine/body information, ACSEB, shown in the third column of the Table, which were assigned to each aircraft type. The three characters in the ACSEB code have the following interpretation:

FIRST LETTER
     H: heavy aircraft, 300,000 lbs or more maximum gross take-off weight (GTOW)
     L: large aircraft, less than 300,000 lbs but more than 12,500 lbs (GTOW)
     S: small aircraft, 12,500 lbs or less (GTOW)
     O: other
SECOND CHARACTER: Number of engines

THIRD LETTER:
     S: standard width body (jet)
     W: wide body (jet)
     P: piston engines
     T: turbo prop engines
     H: helicopter

Having determined the size/engine/body code, the operating costs of Tables 2.4 and 2.5 were extracted from CAB Service Segment Data, (Reference (5)), from an FAA study (Reference (6)) and from an EPA study (Reference (7)). Costs for helicopters are entered as zero, because they are not usually affected by air traffic delays. It is noticed that costs while waiting to take-off (TCOST) are less than those while waiting to land (LCOST) because of different engine settings.

     Passenger load data (LOAD and LOAD∅) are employed to calculate passenger waiting costs. Passenger load variations by (1) aircraft type, (2) airport, and (3) time of day were obtained from

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TABLE 2.3 EQUIPMENT TYPES AND OPERATING COSTS

	AC3LC[1]	ACSEB[2]	TCOST[3]	LCOST[4]
1	ACD	S2T	$80.63/hr.	$96.76/hr.
2	A24	L2T	339.89	385.27
3	A50	S2P	39.67	47.60
4	BBR	S2P	39.67	47.60
5	BNI	S2P	39.67	47.60
6	BNT	S3P	52.83	63.40
7	BTP	S2T	80.63	96.76
8	B18	S2P	39.67	47.60
9	B80	S2T	80.63	96.76
10	B99	S2T	80.63	96.76
11	CES	S1P	13.17	15.81
12	CVR	L2T	339.89	385.27
13	CV2	L2P	260.29	294.13
14	CV4	L2P	260.29	294.13
15	CV5	L2T	339.89	385.27
16	CV6	L2T	339.89	385.27
17	C46	L2P	260.29	294.13
18	DC3	L2P	260.29	294.13
19	DC6	L4P	711.83	784.23
20	DDV	S2P	39.67	47.60
21	DHC	L2P	260.29	294.13
22	DTO	S2T	80.63	96.76
23	FH7	L2T	339.89	385.27
24	F27	L2T	339.89	385.27
25	GGM	S1P	13.17	15.81
26	GGS	S2P	39.67	47.60
27	HRN	L4T	929.52	1027.24
28	LEC	L4T	929.52	1027.24
29	MR4	L2T	339.89	385.27
30	MU2	S2T	80.63	96.76
31	N26	L2T	339.89	385.27
32	PAZ	S2P	39.67	47.60

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TABLE 2.3 EQUIPMENT TYPES AND OPERATING COSTS (continued)

	AC3LC [1]		ACSEB [2]	TCOST [3]	LCOST [4]
33	PCB		S2T	80.63	96.76
34	PCH		S1P	13.17	15.81
35	PDS		L4P	711.83	784.23
36	PHP		L2T	339.89	385.27
37	PNV		S2P	39.67	47.60
38	PPS		S2P	39.67	47.60
39	PRP		L2P	260.29	294.13
40	PR4		S2P	39.67	47.60
41	SKV		S2T	80.63	96.76
42	ST2		L2T	339.89	385.27
43	SWM		S2T	80.63	96.76
44	S55		O1H	0.00	0.00
45	S61		O1H	0.00	0.00
46	TB8		S2P	39.67	47.60
47	TS4		S2T	80.63	96.76
48	Y11		L2T	339.89	385.27
49	Y14		L4P	711.83	764.23
50	Y18		L4T	929.52	1027.24
51	402		S2T	80.63	96.76
52	47J		O1H	0.00	0.00
53	601		S2P	39.67	47.60
54	748		L2T	339.89	385.27
55	DHO		S1P	13.17	15.81
56	M20		S1P	13.17	15.81
57	TRK		S1P	13.17	15.81
60	A3B		H2W	494.67	678.00
61	B11		L2S	393.93	500.62
62	B3J		H4S	566.29	807.04
63	DC8		H4S	566.29	807.04
64	DC9		L2S	393.93	500.62
65	D10		H3W	691.27	1075.00
66	D8S		H4S	566.29	807.04

TABLE 2.3 EQUIPMENT TYPES AND OPERATING COSTS (continued)

	AC3LC[1]	ACSEB[2]	TCOST[3]	LCOST[4]
67	D9S	L2S	393.93	500.62
68	D9S	L2S	393.93	500.62
69	F82	L2S	393.93	500.62
70	L10	H3W	691.27	1075.00
71	511	L2S	392.93	500.62
72	V10	L4S	544.95	750.00
73	707	H4S	566.29	807.04
74	72S	L3S	469.44	625.00
75	720	L4S	544.95	750.00
76	727	L3S	469.44	625.00
77	735	L2S	393.93	500.62
78	737	L2S	393.93	500.62
79	74L	H4W	887.87	1472.03
80	747	H4W	887.87	1472.03
81	880	L4S	544.95	750.00
82	990	L4S	544.95	750.00
83	462	H4S	566.29	807.04
84	486	H4W	887.87	1472.03
85	LJT	L2S	393.93	500.62

NOTES   (1)   AC3LC = Aircraft three-letter code designator

          (2)   ACSEB = Aircraft size/engine/body code (see text)

          (3)   T COST = Aircraft operating cost, waiting to take-off

          (4)   L COST = Aircraft operating cost, waiting to land

TABLE 2.4 AIRCRAFT OPERATING COSTS/HOUR

ACSEB (1)	L COST (2)	T COST (3)	L/T FUEL RATIO (4)	NOTE
H4W	1472.	888.	.287	(5)
H3W	1075.	691.	.287	(5)
H2W	678.	494.	-	(7)
H4S	807.	566.	.327	(5)
L4S	750.	545.	-	(7)
L3S	625.	469.	.412	(5)
L2S	500.	394.	.415	(5)
L4T	1027.	930.	.500	(6)
L4P	784.	712.	-	(7)
L2T	385.	340.	.500	(6)
L2P	294.	260.	.500	(6)
S2T	97.	81.	.500	(6)
S3P	63.	53.	.500	(6)
S2P	48.	40.	.500	(6)
S1P(4+)	16.	13.	.500	(6)
S1P(1-3)	11.	9.	.500	(6)

NOTES:

(1) Aircraft size/engine/body code (see p. 2-13 of text.)

(2) Landing operating cost, from Table 2.5, (dollars/hr)

(3) Takeoff operating cost (dollars/hour)

(4) Ratio of fuel consumption rate during takeoff and idle to fuel consumption rate during approach, obtained from Reference (6).

(5) TCOST obtained by applying T/L fuel ratio to fuel and oil and engine maintenance costs of Table 2.5, and adding to other costs of Table 2.5.

(6) TCOST obtained as in Note (5) above, except that a T/L fuel ratio of .5 was assumed. For S type aircraft, the fuel cost component of L COST was assumed to be 1/3 of L COST.

(7) See Note (3) on Table 2.5.

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TABLE 2.5 BREAKDOWN OF AIRCRAFT OPERATING COSTS (DOLLARS PER BLOCK HOUR)

	Crew	Fuel And Oil	Maintenance Airframe	Maintenance Engine	Maintenance Burden	Total	Note
H4W	336.	587.	139.	234.	177.	1472.	(1)
H3W	291.	388.	102.	152.	141.	1075.	(1)
H2W	-	-	-	-	-	678.	(3)
H4S	250.	299.	70.	61.	127.	807.	(1)
L4S	-	-	-	-	-	750.	(3)
L3S	219.	218.	55.	46.	86.	625.	(1)
L2S	192.	152.	53.	32.	71.	500.	(1)
L4T	391.	195.	169.	74.	198.	1027.	(1)
L4P	-	-	-	-	-	784.	(4)
L2T	124.	91.	59.	45.	66.	385.	(1)
L2P	97.	68.	38.	41.	51.	294.	(1)
S2T	-	-	-	-	-	97.	(2)
S3P	-	-	-	-	-	63.	(3)
S2P	-	-	-	-	-	48.	(2)
S1P (4+)	-	-	-	-	-	16.	(2)
S1P (1-3)	-	-	-	-	-	11.	(2)
O1H	119.	59.	179.	97.	-	454.	(1)

NOTES:

(1) Reference (4)

(2) Reference (5)

(3) Extrapolated or interpolated from similar types with different number of engines.

(4) Obtained from L4T cost by application of empirical prop/turboprop cost ratio of .76.

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Reference (8). The data cover 28 aircraft types, 24 airports and 24 hours, but entries are sparse or missing for many combinations. Only departing loads are available. Moreover, the data are based on a single month's sample at the airports involved: Table 2.6 gives the available data for jets at the 24 airports, averaged over all hours of the day and month. The approximate aircraft seating capacity is also given, (column 3 of the Table). Using the seating capacities a nominal 50% load factor was assumed to derive the passenger loads for aircraft-airport combinations for which no data were available. The complete data base is given in Appendix B-3, where the array LOAD (I,J) gives the load at airport I, numbered as shown in Table 2.6, on aircraft type J. Zeros indicate no data available. The simulator fills in these zeros, as well as the loads for airports not listed, by 50% of the aircraft capacity, LOAD$\emptyset$ in the Appendix.

The hourly variation of passenger load at the 24 airports is shown in Appendix B-3 in the array HFACT(I,J), which gives the number of passengers per departing seat at airport I, numbered as shown in Table 2.6, at local hour J, starting at 00.00, normalized to the average number of passengers per seat throughout the day, expressed in percent. For airports not available in Reference (8), the average value of HFACT for MSY, STL, TPA, MSP, SEA, and IAH was taken and stored in HFACT0 in Appendix 3-C. It is believed that the six smaller airports are more representative of the remaining airports in the U.S. than are the other 18 for which data are available.

Since gate departure lateness affects only those passengers that board the aircraft, rather than the total departing load, it is necessary to adjust the load data above by the ratio of boarding to total departing passengers for B-delay calculation. An analysis of the U.S. CAB Service Segment Data for the 2nd Quarter of 1974 yielded a percentage of continuing passengers for 31 airports, as shown in Table 2.7. When the percent continuing passengers is subtracted from 100, the result is the desired ratio of boarding to departing passengers, in percent. For airports not

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TABLE 2.6   JET LOADS AT 24 AIRPORTS, MARCH 1974

ACFT #	ACFT TYPE	SEATS AVAIL.	SEATS OCCUPIED					
			1 ORD	2 ATL	3 JFK	4 LGA	5 SFO	6 LAX
60	A3B	251						
61	B11	74	37		30	48		
62	B3J	144	73	42	65		76	79
63	DC8	146	79	91	88		55	62
64	DC9	77	45	46		40	51	55
65	D10	242	88	91	99	99	100	89
66	D85	172	89	78	71		81	116
67	D9S	93	57	60	39	84	33	46
68	D95	139						
69	F28	69						
70	L10	243	77	79	107	67	108	89
71	S11	174						
72	V10	135						
73	707	122	76		74		76	76
74	72S	126	69	75	68	78	47	38
75	720	121	86				55	65
76	727	97	63	65	71	64	52	60
77	73S	103						
78	737	98	59	42	49	59	36	47
79	74L	305						
80	747	348	108	102	142		156	125
81	880	90	76				82	
82	990	109						
83	Y62	186						
84	Y86	234						
85	LJT	8						

TABLE 2.6 JET LOADS AT 24 AIRPORTS, MARCH 1974 (continued)

	SEATS OCCUPIED							
ACFT	7	8	9	10	12	13	14	15
#	DEN	PHL	EWR	MIA	DCA	PIT	BOS	CLE
60								
61		43	42		41	45	45	47
62	79	46	95	18		60	56	
63	75	91	75	64			80	72
64	39	50	50	62	37	46	47	49
65	69	67	101	73		49	118	81
66	77	95	89	33		46	80	62
67	39	53	64	57	70	52	61	60
68								
69								
70		76	84	81		52	73	
71								
72								
73	71	66	83			55	84	70
74	52	69	63	57	66	46	71	51
75	69			56				
76	62	52	64	61	70	51	61	57
77	46							
78	47	57	57		49	45	77	58
79								
80				118		75	89	99
81	66		73			39	76	
82								
83								
84								
85								

TABLE 2.6 JET LOADS AT 24 AIRPORTS, MARCH 1974 (concluded)

ACFT #	SEATS OCCUPIED									
	16 DTW	17 MSY	20 STL	32 DFW	22 TPA	23 MSP	24 SEA	- IND	29 IAH	- MEM
60										
61	40		51					29		
62	40		45	66	40	47	30	47	100	24
63	76	65		74	55		62		41	30
64		27	38	42		30	27	45	75	92
65	84	61		85	80	57	55		76	31
66	98	62		93	46		52		50	44
67	46	48	44	45	52	42	34	41		
68										
69										
70	69	54	81	95	44			95	68	
71										
72										
73	72		65	62				58	38	46
74	62	56	57	57	51	54	43	48	50	44
75						56	64		45	
76	70	51	59	52	49	43	45	47	57	50
77			41	35						
78	70					46	30			26
79										
80	111			117	93	83	90		146	
81			72							
82										
83										
84										
85										

TABLE 2.7 PERCENT CONTINUING PASSENGERS AT MAJOR AIRPORTS

AIRPORT		PERCENT CONTINUING
1	ORD	4
2	ATL	4
3	JFK	3
4	LGA	2
5	SFO	4
6	LAX	7
7	DEN	8
8	PHL	9
9	EWR	3
10	MIA	2
12	DCA	6
13	PIT	12
14	BOS	4
15	CLE	8
16	DTW	7
17	MSY	12
18	LAS	9
19	HNL	5
20	STL	11
21	FLL	3
22	TPA	14
23	MSP	5
24	SEA	8
25	BAL	13
26	CLT	13
27	MKE	17
28	SLC	10
29	IAH	11
30	IAD	15
31	JAX	18
32	DFW	10

Source: U.S. CAB Service Segment Data, 2nd Quarter, 1974.

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shown in the table, it was assumed that the continuing pas-
sengers were 20% of total passengers. The complete data set of
percent boarding is given in Appendix B-3, under the arrays BOARD
and BOARD0.

Finally, it will be seen that Appendix B-3 also lists the
carrier 2-letter codes under six categories:

STK: Scheduled Trunklines
SLS: Scheduled Local Service, plus New England Airlines.
SIS: Scheduled Intra-State carriers
SIF: Scheduled International, Territorial and Foreign
       Flag Carriers
SCT: Scheduled Commuter/Taxi Carriers
SHO: Scheduled Helicopter and Other

3. MODELS

The ANFS is a calculation of landing, takeoff, and B-type
delays from the demand and capacity data described in the previous
section. The models here presented are simply the rules followed
in the caluclations. Once the delays are calculated, they are
converted to dollars using the input cost coefficients. The rules
for the cost calculation are also described in this section. A
full listing of the ANFS is given in Appendix B-4.

3.1 TIME

The calculation starts at 10:00 GMT and ends 27 hours later,
thus spanning the active flying period from 5:00 AM EST to 3:00
AM HST. The start and stop times are independent of user input,
and have been selected so as to insure zero length queues at the
start and stop of the calculation. It will be noticed that the
stop time 3:00 AM HST (Honolulu) is 8:00 AM EST (New York) of the
following day. The demand data base, however, does not include
the next day's traffic, so that no new traffic will be introduced
in New York after 5:00 AM EST. This confines the delay calcula-
tion to a single day's traffic.

In order to avoid the cost of floating point arithmetic, all
internal calculations are done in integer seconds. This procedure
was found to provide adequate resolution except when a precise
value of operations per hour must be achieved by selection of
the service interval. A one percent resolution error in service
interval produces a one percent error in operations rate, so that
for a typical single-runway rate of 60/hr, the resolution error
is approximately $\pm$ 0.8%. At a rate of 120/hr, the error is
approximately $\pm$ 1.6%. These small capacity errors, however, can
correspond to substantial percent errors in delay, a problem that
was solved in the validation procedure (Section 5) by interpolating
both input and output between runs.

It should be noted that OAG schedules are given in hours and minutes, so that they appear internally in the ANFS as multiples of 60 seconds. The start time (10:00 AM GMT) is expressed internally as 36000 seconds, and the end time (1:00 PM the next day, GMT) is expressed as 133200 seconds.

3.2 SERVICE INTERVAL COMPUTATION

As described in Section 2.2, for each airport of interest the user inputs the airport identifier and a sequence of 24 hourly service intervals, in seconds. This is followed by the percent of all traffic that is non-scheduled, and its distribution, in percent, throughout the 24 hours. These data may be given for up to 32 airports, the remaining airports in the data base being specified under a single fictitious airport ALL.

The service interval input by the user is the average minimum separation time for all aircraft types, both scheduled and non-scheduled. Since the demand data and delay calculation are restricted to scheduled operations only, the simulator converts the input service interval to the equivalent service interval for scheduled operations, as follows: The relations

$$P_T(h) = 1/\sigma_T(h)$$

$$P_T(h) = P_S(h) + P_N(h)$$

$$= 1/\sigma_S(h) + 1/\sigma_N(h)$$

serve to define the processing rates $P_S(h)$, $P_N(h)$, $P_T(h)$ and service intervals $\sigma_S(h)$, $\sigma_N(h)$, $\sigma_T(h)$ for the scheduled, non-scheduled and total traffic components in hour h. The user inputs $\sigma_T(h)$ and the program must calculate $\sigma_S(h)$. The major assumption is that processing rates $P_S(h)$ and $P_N(h)$ are proportional to the hourly demands $V_S(h)$ and $V_N(h)$, i.e.,

$$\frac{P_S(h)}{P_S(h) + P_N(h)} = \frac{V_S(h)}{V_S(h) + V_N(h)}$$

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and

$$\frac{P,(h)}{P_S(h) + P_N(h)} = \frac{V_N(h)}{V_S(h) + V_N(h)}$$

This assumption is equivalent to assuming that the scheduled and non-scheduled demands are both random in time, and that they are served first-come-first-served (FCFS). The value of $V_s(h)$ is obtained from the demand file and its sum over $h=1,2,\ldots,24$ gives $\bar{V}_s$, the total scheduled demand for the day. Then the program calculates $V_N(h)$ as

$$V_N(h) = \frac{\gamma(h)}{100} * \frac{KGA * \bar{V}_s}{100 - KGA}$$

where KGA and $\gamma(h)$ are the values of the non-scheduled traffic fraction and its distribution throughout the day that were input on the second card of each airport, as described in Section 2. From these, the simulator calculates the desired service interval for scheduled traffic, $\sigma_s(h)$:

$$\sigma_s(h) = \sigma_T(h)\left[1 + \frac{\gamma(h)\ (KGA)(\bar{V}_s)}{V_s(h)\ 100\ (100-KGA)}\right]$$

It was found in practice that the above formula occasionally resulted in excessively long service intervals for scheduled flights. Accordingly, the scheduled service interval was limited in the ANFS to be no greater than the interval for non-scheduled flights.

In the case of airport ALL an additional assumption is made: the ratio of non-scheduled traffic to total traffic is constant throughout the day at the input value KGA/100. This gives

$$\sigma_s(h) = \sigma_T(h)/(1 - \frac{KGA}{100})$$

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for all airports not explicitly entered under their three-letter code. It should be noted that this additional assumption applies only to the calculation of service interval, and does not apply to the scheduled demand employed in the simulator for airports under ALL. This scheduled demand for airports under ALL is taken from the OAG for the day and the airport, via the demand file.

3.3 RUNWAY EVENT COMPUTATION

Having calculated the minimum allowable time $\sigma_s(h)$ between completed runway operations for scheduled aircraft, the simulator proceeds to calculate runway events at all airports.

It will be recalled from Section 2. that the demand file contains scheduled <u>gate</u> departures and arrivals, rather than runway operations, the differences being from two to 15 minutes of taxi time, depending on airport layout, runway in use, and type of aircraft. In order to avoid detailed adjustments for these factors, the simulator uses the scheduled gate times as scheduled take-off and landing times. The normal taxi times, therefore, are lumped with flight times, and are taken into account in the minimum normal flight times.

In the description that follows the terms "scheduled departure," "scheduled arrival," and "event", without the word gate, will refer to <u>runway</u> operations as represented by gate arrivals and gate departures in the demand file.

As a first step, the simulator extracts from the itineraries of the demand file all scheduled departures and arrivals at a single airport, and examines them in time order. If any two events are scheduled at less than the minimum runway service interval (for the hour in which the first is scheduled), it reschedules the second event to satisfy the minimum service interval requirement. It then proceeds to the next event at the airport and separates it from the previous, if necessary, by the minimum service interval. This prodecure is carried out for events scheduled within a limited time interval at the airport, and repeated for events at the next airport within the same time

interval. When all airports have been adjusted, the time interval is advanced its own duration and the process repeated for all airports.

The reason for use of a time interval has to do with the propagation of delays. When an event in an itinerary is rescheduled (i.e., delayed), the subsequent events for that aircraft may be affected. Specifically, if a departure is delayed, the associated landing may have to be delayed so that the minimum normal flight time is satisfied. Similarly, adjustment of the landing time may require adjustment of the subsequent takeoff time, if any, so that the gate turn-around time is satisfied. The simulator makes all required future schedule adjustments for an aircraft when it reschedules a takeoff or landing event for that vehicle. It is important that none of these future event adjustments affect the events previously rescheduled at other airports. Hence the event calculation at any one airport is restricted to an interval smaller than the shortest TAU in the file, i.e., shorter than the shortest flight or turn-around time in the demand file. Therefore, the propagation of delays from that event calculation will not affect events at other airports within or prior to the interval.

In the initial stages of developing the ANFS it was estimated that the shortest such interval was 5 to 10 minutes. It soon was discovered that gate turn-around times of less than five minutes were occasionally scheduled on some commuter airlines, and, in fact, zero and negative values were found to occur at airports such as Dulles International, because of their mobile lounges. At the expense of some realism, all itineraries were adjusted to have no TAU less than ten minutes, and this value was adopted for the time interval of computation at each airport before passing to the next airport.

3.4 DELAY COMPUTATION

When the computation interval has been advanced to the end time of the simulation, all runway events will have been recalculated to what may be termed their actual times. The simulator

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then compares these actual times with the original demand file schedules to determine delays by airport.

Landing Delay This is the difference between the actual arrival time and the "ready-to-land" time. The latter is the actual take-off time at the previous airport plus the minimum normal flight time. It will be recalled that the actual take-off and landing times are represented by rescheduled gate times, which is compensated for by the flight times, into which the taxi times have been lumped. The result is representative of the air delay on landing.

Take-off Delay It is assumed that the aircraft actually leaves its gate at a time determined by adding the gate turn-around time to the actual gate arrival time (the latter having been calculated as landing time in the simulator), but not earlier than the scheduled gate departure in the demand file. The actual take-off time was also calculated in the simulation. Subtracting actual gate time from actual take-off time gives take-off delay.

B-Delay This is calculated as actual time of gate departure, described above, minus the gate departure time originally scheduled in the demand file.

Total Delays The delays calculated as above for each event are aggregated and stored by hour for the airport. The total of the three types of delay at all airports is also stored by hour.

3.5 COST COMPUTATION

The delays calculated, as above, for each event at an airport are converted to dollar amounts by use of the input cost parameters. (See Section 2.3.)

First, the number of passengers is calculated using the load level stored in LOAD for the aircraft and airport involved, if the airport is one of the 24 for which data are available, or in LOAD0 if it is not one of the 24 airports. The passenger load is then multiplied by the hourly load factor HFACT/100 for the airport and hour, if the airport is one of the 24 for which data

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are available, or by the factor HFACT0/100 for the hour if it is not one of the 24 airports. In either case, the result is an estimate of the number of passengers involved in the delay for the particular airport, aircraft type and local hour.

Landing delay cost is obtained by multiplying the landing delay by the passenger load and PCOST, the value of passenger time, and adding the result to the product of landing delay and the landing operating cost, LCOST, for the appropriate aircraft type.

Take-off delay costs are calculated similar to the landing delay costs, except that the operating costs for takeoff, T COST, are used instead of LCOST.

B-delay costs are obtained by multiplying the boarding passenger load BOARD or BOARDØ by P COST and by the B-delay.

Finally, the total costs of each type (i.e., landing, takeoff an B-delay) for all airports are calculated for each hour.

3.6 CONTROL PARAMETERS

The use of the four control parameters, EXPFAC, PLEVEL, MAXGT and KSLACK will now be discussed.

EXPFAC allows for the expansion of traffic by adjusting the service interval. It is assumed that both scheduled and non-scheduled traffic are to be increased by the fraction EXPFAC/100. The service interval σ_s(h) is multiplied by EXPFAC/100, thus allowing for servicing (EXPFAC/100) aircraft for each aircraft in the demand data base. This procedure is much simpler than inserting whole aircraft into the demand data base, thus rearranging all schedules, and it gives reasonable average delays for small traffic expansion levels (say, 10% or EXPFAC/100 = 1.10). The process is most accurate for saturation conditions, and less accurate when the airport is operating below capacity.

PLEVEL is the total level of all types of delay, in aircraft-minutes, that must accumulate at an airport over the day for that airport to be included in the printout. Setting PLEVEL at, say,

20 aircraft-minutes of delay will shorten the print out substantially, but not affect the total system delay or cost, which always are printed out and which always include all airports.

MAXGT is the maximum allowable gate turn around time. It was found that the search process used to derive gate turn-around times (See Section 2.1) occasionally resulted in long turn-around times, because only a few aircraft of the given type were scheduled to pass through the airport. In such cases it is possible that none of the aircraft were scheduled to turn around in minimum time, so that the search yielded excessively long turn-around times. It was found that a limit of MAXGT = 60 minutes was effective in avoiding the problem. It should be noted also that a lower limit on turn-around times is set by the computation interval (See Sec. 3.3).

KSLACK allows the user to increase the gate turn-around time of all aircraft at all airports by an amount of KSLACK minutes. The value KSLACK = 9 has been adopted for the ANFS as a result of the validation tests described in Section 5. In general, however, the gate turn-around time is not allowed to exceed either the amount of ground time actually scheduled for the aircraft, or the amount MAXGT + KSLACK. Because of these limits the reduction observed in the system-wide average of ground slack time is usually less than the increase KSLACK in ground time that is input.

4. OUTPUT

The ANFS output consists of (1) a repetition of the demand
and service interval data inputs for the airports specified by
the user, (2) the delays for all airports in the data base
for which the total delay exceeds the control parameter PLEVEL,
and (3) a summary of system-wide delays. A sample output is
given in Appendix B-5.

4.1 INPUT DATA

Demand and capacity information are printed out for each
airport specified on the capacity input cards (See Section 2.2)
including the airport ALL. If the user specifies capacity data
for no airport except ALL, only the latter will be printed. If
he specifies an airport not in the demand data base, the message
"INPUT AIRPORT XXX NOT IN DATA BASE" will be printed out, and the
data input for that airport will be ignored. Similarly, the
program will ignore airports beyond the first 32 that are identi-
fied as being in the data base, as well as any inserted after the
airport ALL.

For each input airport the output shows the scheduled and
non-scheduled volumes by local hour. The volumes are based on
the demand data base and the non-scheduled parameters KGA and
GFAC (See Section 2.2). The effect of EXPFAC is not included in
the volumes that are printed out.

Following the volumes, the output shows the service intervals
by local hour for scheduled and total traffic components, which
are the values of $\sigma_s(h)$ and $\sigma_T(h)$, h = 1,2,...,24, described in
Section 3.2. The service intervals printed out include traffic
expansion due to EXPFAC, i.e., they have been multiplied by
EXPFAC/100.

At the end of the demand and service interval printout the
heading appears: "MEAN GROUND SLACK TIME (minutes)." The number
printed out is the average, for all aircraft in the demand data

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base, of the difference between the scheduled ground time and the minimum gate turn-around time (TAU) stored in the data base, after the latter has been adjusted for MAXGT as described in Section 3.6. Increasing the input parameter KSLACK will reduce the average ground slack time, but not in a one-to-one ratio.

4.2 AIRPORT DELAYS AND COSTS

If the 24-hour total of landing, take off and B-delay for an airport equals or exceeds the number of aircraft-minutes input in the parameter PLEVEL, the program will print out the following for the airport: (See Appendix B-5)

Landing delay by GMT hour, followed by the total landing delay for the day and total cost of landing delays for the day. Delays are in aircraft-minutes, costs are in dollars.

Take off delay and cost, in the same format as landing delays.

A-delay and cost, which is defined as the sum of the landing and take off delays and costs, in the same format.

B-delay and cost, which pertain only to gate departure lateness, in the same format as above.

The airport is identified by its 3-letter code, as given in the OAG, preceded by the internally assigned airport number.

4.3 SYSTEM DELAYS AND COSTS

After the outputs for individual airports, the heading "TOTAL DELAY IN HOURS" is printed, followed by the hourly delays in aircraft-hours for the entire system of airports in the data base. The delays are broken out by landing, takeoff, A-delay and B-delay, with totals for the day shown in the right most column. This is followed by the heading "TOTAL COST IN THOUSANDS OF DOLLARS" and the costs corresponding to the total delays.

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5. VALIDATION

The ANFS was validated in two stages, corresponding to the two most critical areas in the modelling process.

First, the linkages produced by the flight schedule generator were compared to airframe itineraries obtained from two trunk line carriers. This process was intended to verify the accuracy of the flight schedule generator of the ANFS.

Second, the B-delays calculated by the ANFS were compared with the B-delays actually experienced by a large trunk line carrier on February 16, 1976. The airport capacity in the ANFS was adjusted to make the actual and the simulated landing delays equal at the selected airport for the carrier. This process was intended to verify the relation between A-delay and B-delay as calculated in the ANFS.

The two stages are described in the next two sections. Appendix A describes more fully the data on which the validation is based, and gives a further analysis of the B-delays experienced by two carriers on selected days.

5.1 VALIDATION OF THE FLIGHT SCHEDULE GENERATOR

As described in Section 2.1, the flight schedule generator links together Official Airline Guide (OAG) flights arriving at a specific airport with flights of the same carrier and equipment type leaving that airport. This is done for all airports in the OAG. The resultant strings of legs, or aircraft itineraries, are intended to resemble the itineraries of real airframes. In order to check the generated itineraries, two types of test were performed: single linkage tests and multiple linkage (i.e., itinerary) tests.

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5.1.1 Single Linkage Tests

Airframe itineraries were obtained from a large trunk line carrier for September 3, 1975. The ANFS schedule file (ANFS.DAT) was generated for that day and the flight linkages for the carrier were extracted. They were then compared, on an airport-by-airport basis, with the collected data. Linkages generated between incoming and out going flights that bore the same flight number were considered correct. Those between flights with different flight numbers were counted correct if the two flights were found in the trunk line data and if they did, indeed, belong to the same airframe as indicated in the data.

The results of the tests are given in Table 5.1.1. The rows in the Table correspond to versions produced by successive modifications of the basic algorithm described in Section 2.1. The versions are as follows:

> Version #0: Basic Algorithm (See Section 2.1)
>
> Version #1: All shuttle flights (distinguished in the OAG by origin, destination, and flight number) were changed to single-leg flights. Further, all single leg and shuttle flights were excluded from the comparison.
>
> Version #2: Linkages between early arrivals (00:00 to 09:00 GMT) and late departures were eliminated.
>
> Version #3: Linkages were eliminated for which the departure time was less than the arrival time plus thirty minutes (40 minutes for L1011, 747 and DC10). The original algorithm generated such linkages on the assumption that the departures were diurnally cyclic, i.e., repeated on the next day.
>
> Version #4: Linkages of flights with the same flight number that were severed by the previous modification were restored, provided the unadjusted arrival time did not exceed the departure time.

As a result of the above four modifications to the original algorithm, about 94% of the linkages generated were correct (i.e., found to have a counterpart in the data). Approximately 59% of these were linkages between similar flight numbers.

TABLE 5.1.1   RESULTS OF SINGLE LINKAGE TESTS

VERSION	TOTAL LINKS IN TEST	LINKS WITH SAME FLT NO	LINK WITH DIF-FERENT FLT NOS		% CORRECT (ALL CASES)
			RIGHT	WRONG	
0	1219	602	392	225	81.5
1	1150	602	392	156	86.4
2	1091	602	395	94	91.4
3	879	466	350	63	92.8
4	1007	594	350	63	93.7

It should be noted, however, that a complete itinerary has, typically, four or five legs and three or four linkages. If the chance of any single linkage being correct is .94, then one might expect $(.94)^3$ or $(.94)^4$ probability of a complete itinerary being correct. These fractions are .83 and .78 respectively. The tests of correctness for complete itineraries are described next.

5.1.2 Itinerary Tests

A second set of itineraries were obtained from another trunk line carrier for February 16, 1976. These data contained 1,391 flight legs. Once again, an ANFS schedule file was generated for the same day, and all flights of the given carrier were extracted. Some 1,374 flight legs and 321 itineraries were obtained. Each of the 321 itineraries was compared with the field data, starting with the first leg of the itinerary. If a similar leg was found in the data, then the next leg in the field data itinerary was compared with the next leg in the generated itinerary, etc. When a mismatch occurred, or when the end of either itinerary was reached, the comparison was stopped. All generated legs that had been matched successfully with the data were counted as correct, and all remaining legs (if any) in the generated itinerary were counted as incorrect. Proceeding in this way, all itineraries were checked, and the total number of correct legs and itineraries tabulated. (Table 5.1.2)

The interpretation of Table 5.1.2 is as follows: An itinerary was considered totally correct if all its legs were correct (i.e., found, in order, in the field data). It was considered partially correct if some, but not all, of its legs were correct. Finally, it was counted as "incorrect" if none of its legs were considered correct. Because of the rules stated above, an itinerary was considered incorrect if, and only it, its first leg was not found in the field data. This could occur only if the OAG schedule for the first leg had no counterpart whatever in the data.

The percentage of "incorrect" itineraries is about 19%, a rather high discrepancy. It appears that a substantial number

TABLE 5.1.2   RESULTS OF ITINERARY TESTS

NUMBER OF LEGS GENERATED	1374
NUMBER OF ITINERARIES GENERATED	321
NUMBER OF CORRECT LEGS	818
NUMBER OF TOTALLY CORRECT ITINERARIES	130
NUMBER OF PARTIALLY CORRECT ITINERARIES	131
NUMBER OF INCORRECT ITINERARIES	60
NUMBER OF LEGS IN INCORRECT ITINERARIES	206

of flight legs in the OAG did not appear in the data exactly as
scheduled, i.e., with the originally scheduled origin, destination,
departure time, arrival time and aircraft type. The ANFS schedule
generator, of course, can not produce correct linkages employing
legs that do not appear in the field data. Hence, the 60 incorrect
itineraries should be excluded in determining the accuracy of the
flight linkage generator.

When the incorrect itineraries are excluded, the linkage
generator accuracy may be estimated as K:

K = (number of correct itineraries)
    ÷(total number of itineraries, minus incorrect itineraries)
  = 130÷(321 - 60)
  = 50%

A more accurate measure would allow for the correct legs in
the partially correct itineraries as well:

K = (number of correct legs) ÷ (total number of legs, minus
    legs in incorrect itineraries)
  = 818 ÷ (1374 - 206)
  = 70%

The latter figure must be considered a lower bound on the
number of correctly linked legs. The true figure is probably
greater because some of the partially correct itineraries may have
contained legs not in the field data at all, as in the case of the
initial leg of each incorrect itinerary. On a random basis (i.e.,
assuming the spurious legs were randomly distributed among the
generated itineraries) one would estimate the probability of any
one leg being spurious as 60/.321 or .187. Therefore, the probabi-
lity of an itinerary being totally correct is .437 if it had 4
legs and .355 if it had 5 legs. The likelihood of a partially
correct itinerary would be 1.0-.437-.187 =.376 for 4 legs and
(1.0-.355-.187) =.458 for 5 legs. Finally, the likelihood of an
incorrect itinerary would be .187. These theoretical estimates
are compared to the actual fractions of correct, partially correct,
and incorrect itineraries in Table 5.1.3.

TABLE 5.1.3 FRACTIONS OF CORRECT, PARTIALLY
CORRECT AND INCORRECT ITINERARIES

	THEORETICAL*		
	4-LEG	5-LEG	ACTUAL
TOTALLY CORRECT	.437	.355	.40
PARTIALLY CORRECT	.376	.458	.41
INCORRECT	.187	.187	.19

*BASED ON A RANDOM DISTRIBUTION OF SPURIOUS LEGS, AND A
PROBABILITY OF .187 OF A LEG BEING SPURIOUS

Examination of Table 5.1.3 shows that the actual number of itineraries in each category falls between the 4-leg and 5-leg prediction. Since the average number of legs per itinerary was actually 4.28, one concludes that the observed number of partially correct itineraries may (possibly) have been produced solely by spurious legs in the data. For this reason, 70% must be considered a low estimate to the true percentage of correct legs.

5.2 VALIDATION OF THE DELAY SIMULATOR

The data employed for the itinerary tests described above contained, before editing, over 1400 flight legs executed by about 350 aircraft on February 16, 1976. The data for each leg contained the aircraft tail number, flight number, origin and destination airport codes, scheduled gate departure and arrival times, and actual gate departure and arrival times. These data were edited for airports not in the ANFS data base (e.g., ITO, YVR, GUA), for key punching errors, and for miscellaneous inconsistencies (e.g., departure and arrival at same airport). The editing affected fewer than 2% of the flight legs.

The modified data were employed in two ways, shown in Figure 5.2.1. First, the scheduled departure times were used to drive the simulator, which calculated A- and B- type delays. Then the actual departure and arrival times were used to derive A- and B-type delays for comparison with the simulator output. The comparison was made only for the flights of the given trunk line carrier at selected airports. Before making the comparison, the airport capacity in the simulation was adjusted so that the total simulated landing delay equalled the total actual landing delay over the day. The B-delays were compared to give a measure of simulator performance. The process was carried out for three airports: ORD, DEN, SFO.

5.2.1 Calculation of A-Delay From Field Data

The intent of the A-delay calculation was to isolate L, the landing delay on arrival at the airport of interest.

```
                        ┌─────────────┐
                        │ FIELD DATA  │
                        │    FOR      │
                        │  16 FEB 76  │
                        └─────────────┘
                               │
                        ┌─────────────┐
                        │  EXTRACT    │
                        │  FLIGHTS    │
                        │  TO/FROM    │
                        │    APT      │
                        └─────────────┘
```

EXTRACT SCHEDULED
DEPARTURE TIMES,
ORIGIN, DESTINATION

ADD AIRCRAFT TYPE

ADD AIR AND
GROUND TIMES

ANFS
FLIGHT
FILE

MERGE WITH FULL
ANFS FLIGHT FILE

EXTRACT TRAFFIC
TO/FROM APT

CALCULATE
A-DELAYS

CALCULATE
B-DELAYS

Landing
Delay
for APT

B-delays
for APT

Landing
Delays
for APT

B-delay
for APT

AIRPORT NETWORK
FLOW SIMULATOR

FIGURE 5.2.1   SIMULATOR VALIDATION PROCESS

It was calculated as

    L = A - S
    A = actual flight time
      = (actual gate arrival minus actual gate
        departure at preceding airport
    S = scheduled flight time
      = (scheduled gate arrival - scheduled gate
        departure at preceding airport

When this calculation was made for ORD, several flights appeared to have negative landing delays (See Table 5.2.1). The negative values are possibly due to

    (1) Extension of scheduled flight times to allow for delays
    (2) Tail winds encountered in flight, or use of a shorter
        than normal route for departure, arrival or cruise.

On the opposite side of the ledger, the value of L includes delays other than those in landing, such as take-off delays at the preceding airport, enroute delays, and unexpected head winds.

It is not possible, without supplementary data, to distinguish landing delays from the other types included in L. However, a partial correction was made for schedule extension, item (1) above, which tends to make L negative, by using flight times derived from the ANFS flight data base instead of the value of S shown above.

These flight times were obtained by extracting all the scheduled flight times from the Official Airline Guide (OAG) for the test day for each origin/destination pair and aircraft type. The minimum of the scheduled times was selected as the flight time for the origin/destination pair and aircraft type. This was used in place of S in the calculation of L above. The results are shown in Table 5.2.2. It can be seen that the positive delays are increased by about 12% but no change occurs in the negative delays. This would suggest that the negative delays are due to tail winds encountered enroute, but the sample size (six out of 186) is too small to draw any conclusion.

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TABLE 5.2.1 A-DELAYS AT ORD CALCULATED FROM FIELD DATA (PRELIMINARY)

GMT HOUR	POSITIVE DELAYS (NO ACFT)	(ACFT-MINS)	NEGATIVE DELAYS (NO ACFT)	(ACFT-MINS)
10:	0	0	0	0
11	1	3	0	0
12	1	0	2	-8
13	10	20	3	-16
14	2	0	1	-6
15	18	143	0	0
16	9	24	0	0
17	4	49	0	0
18	17	259	0	0
19	18	178	0	0
20	8	108	0	0
21	9	199	0	0
22	16	270	0	0
23	20	1005	0	0
24	5	124	0	0
25	15	820	0	0
26	18	946	0	0
27	6	299	0	0
28	1	20	0	0
29	2	24	0	0
30	0	0	0	0
	180	4491	6	-30

TABLE 5.2.2 A-DELAYS AT ORD CALCULATED
FROM FIELD DATA

GMT HOUR	POSITIVE DELAYS (NO ACFT)	(ACFT-MINS)	NEGATIVE DELAYS (NO ACFT)	(ACFT-MINS)
10:	0			
11	1	3	0	0
12	1	0	2	-8
13	10	22	3	-16
14	2	0	1	-6
15	18	149	0	0
16	9	28	0	0
17	4	49	0	0
18	17	279	0	0
19	18	211	0	0
20	8	121	0	0
21	9	212	0	0
22	16	358	0	0
23	20	1121	0	0
24	5	138	0	0
25	15	884	0	0
26	18	1026	0	0
27	6	311	0	0
28	1	20	0	0
29	2	12	0	0
30	0	0	0	0
	180	4944	6	-30

The process of extracting A-delays just described for the ORD data was repeated for the trunk line carrier's flights to SFO and DEN. The results are shown in Tables 5.2.3 and 5.2.4.

5.2.2 Calculation of B-Delay From Field Data

The B-delay employed in validation was taken to be the difference between actual and scheduled gate departure, with the following adjustments:

(1) Flights having no incoming leg to the airport of interest were excluded.

(2) Negative departure lateness (actual gate departure preceding scheduled gate departure) were excluded.

(3) Gate departure lateness at the preceding up-line station were subtracted from gate departure lateness at the airport of interest.

(4) Gate departure times were reduced by the amount that actual ground time exceeded the scheduled ground time, on the assumption that the excess represents aircraft turn-around delay rather than B-delay.

The exclusion in (2) was applied also to delays that were negative after corrections (3) and (4) were made. The results for ORD, SFO and DEN are shown in Table 5.2.5.

The delays shown in the Table may overestimate the actual B-delays on gate departure because they may include delays due to equipment problems or gate availability problems, as well as delays in loading and aircraft checkout. It is not likely that they underestimate B-delays, however, since this would require an error in recording actual or scheduled gate departure, or, perhaps, aircraft maintenance or preparation done at the dock or on the apron after push-back.

TABLE 5.2.3 A-DELAYS AT SFO CALCULATED FROM FIELD DATA

GMT HOUR	POSITIVE DELAYS		NEGATIVE DELAYS	
	(NO ACFT)	(ACFT-MINS)	(NO ACFT)	(ACFT-MINS)
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	1	0	0	0
15	5	20	0	0
16	3	18	0	0
17	1	11	2	-12
18	5	33	0	0
19	7	52	0	0
20	8	146	0	0
21	4	39	0	0
22	3	35	1	-12
23	5	50	1	-4
24	3	53	0	0
25	11	93	0	0
26	8	103	0	0
27	4	19	1	-4
28	6	42	0	0
29	8	123	0	0
30	7	52	0	0
31	1	4	2	-3
	90	893	7	-35

TABLE 5.2.4   A-DELAYS AT DEN CALCULATED
FROM FIELD DATA

GMT HOUR	POSITIVE DELAYS		NEGATIVE DELAYS	
	(NO ACFT)	(ACFT-MINS)	(NO ACFT)	(ACFT-MINS)
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	1	7	1	-1
16	7	44	1	-1
17	3	18	2	-6
18	8	40	1	-1
19	2	9	0	0
20	9	53	1	-1
21	2	27	1	-5
22	7	26	2	-6
23	0	0	0	0
24	10	66		
25	4	25	1	-5
26	5	37	1	-1
27	5	24	0	0
28	0	0	0	0
29	1	7	0	0
30	0	0	0	0
	64	383	11	-27

TABLE 5.2.5 B-DELAYS AT ORD, SFO AND DEN
CALCULATED FROM FIELD DATA

GMT HOUR	ORD		SFO		DEN	
	(NO ACFT)	(ACFT-MINS)	(NO ACFT)	(ACFT-MINS)	(NO ACFT)	(ACFT-MINS)
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	1	19	0	0	0	0
13	5	41	0	0	0	0
14	13	0	0	0	0	0
15	1	0	1	0	0	0
16	18	36	5	1	2	0
17	9	0	3	2	7	15
18	2	8	1	0	1	0
19	16	76	3	10	10	6
20	15	110	6	12	3	3
21	13	159	7	59	7	28
22	7	68	6	2	1	6
23	10	59	3	10	11	20
24	16	602	2	2	1	0
25	9	331	4	24	7	18
26	10	416	8	48	5	7
27	10	327	9	155	8	24
28	4	139	2	0	2	12
29	0	0	4	38	0	0
30	0	0	4	18	0	0
31	0	0	3	2	0	0
	159	2343	71	383	65	133

5.2.3 Calculation of A- and B-Delay by the ANFS

While the field data represents actual flights, the ANFS
flight schedule file is based on the OAG schedule for the trunk
line on the given day. More over, the field data contains actual
airframe itineraries, while the ANFS flight file contains itiner-
aries generated by the linkage algorithm described in Section 1.1.
In order to exclude inaccuracies introduced by the flight linkage
algorithms, which were evaluated in the preceding Section, the
actual aircraft itineraries and departure times for the trunk line
carrier were substituted into the ANFS flight schedule file in
place of those generated by the linkage algorithm. By this means
any discrepancy between actual and simulated B-delays may be
attributed primarily to the ANFS ground delay propagation model.

In order to put the actual itinerary into the form of the
ANFS flight file, i.e., a series of events, it was necessary to
obtain, for each event: (1) airport number, (2) scheduled event
time, (3) minimum time to next event, and (4) carrier/equipment
type code. This was done as follows:

(1) The field data contained the airport 3-letter
     identifier, which gave the airport number via a look-
     up table
(2) The scheduled event time was taken directly from the data
(3) The minimum flight times and ground times were extracted
     from the ANFS flight file. In the cases where the ANFS
     flight file contained no minimum ground or air time for
     the aircraft, the scheduled ground or air times given
     in the data were used.
(4) The equipment type code was based on the first two
     digits of the tail number as given in the field data.

The last item, equipment type code, was employed to extract
item (3), the minimum flight or ground times, from the ANFS flight
file. As described in Section 1.1, the ANFS flight file contains

the minimum flight or ground times for the aircraft types and airports of interest. By identifying the aircraft type in the field data it was simple to extract the appropriate flight or ground time from the ANFS flight file itself.

Having substituted the actual itineraries and scheduled times for the trunk line carrier into the ANFS flight file, a final step was taken before running the simulator. This was to extract from the revised flight file all the scheduled itineraries to, from or through the airport of interest. The file thus obtained for the first test airport, ORD, contained about 800 itineraries and 8000 events. The statistics of the extracted files for all three airports are given in Table 5.2.6. (By comparison, the unextracted ANFS flight file has 152,888 words, 5,402 itineraries, 38,222 events, and 665 airports.)

In running the simulator the minimum inter-operation time at the airport was varied from 20 seconds (corresponding to a capacity of 180 operations per hour) to 80 seconds (corresponding to 45 operations per hour); the non-scheduled traffic profiles employed were fixed for all runs and are given in Table 5.2.7. These profiles are based on References (3) and (4). As described in Section 3, the non-scheduled profiles serve to adjust the effective inter-operation time for scheduled flights.

The cost data and cost models were not included in the validation procedure since no field data were taken on operating costs.

5.2.4 Comparison of ANFS Output with Field Data

The output delays of the simulator as a function of the service interval are shown in Figure 5.2.2 for ORD, in Figure 5.2.3 for SFO, and in Figure 5.2.4 for DEN. The vertical axis shows total landing delay and total gate departure lateness (B-delay) for the trunk line carrier when the service interval was constant through out the day at the value shown on the horizontal axis. These plots show the expected sharp increase of delay with service time.

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TABLE 5.2.6   STATISTICS OF VALIDATION FLIGHT FILES
FOR ORD, SFO AND DEN

AIRPORT ID	:	ORD	SFO	DEN
File Size (words)	:	31,552	13,992	10,696
Number of Itineraries in File	:	782	381	291
Number of Events in File	:	7,888	3,498	2,674
Number of Airports in File	:	237	142	153

TABLE 5.2.7 NON-SCHEDULED TRAFFIC PROFILES USED
FOR VALIDATION RUNS

LOCAL HR	ORD	SFO	DEN
0:00	1%	2%	0%
1	1	1	0
2	1	0	1
3	1	0	1
4	1	1	1
5	1	1	1
6	1	2	1
7	5	4	3
8	6	8	5
9	6	6	8
10	6	5	7
11	5	5	8
12	6	8	6
13	6	6	9
14	6	6	5
15	6	6	6
16	7	3	6
17	7	5	8
18	7	6	10
19	7	7	7
20	6	7	3
21	4	5	2
22	2	3	2
23	1	3	0
	100	100	100
NON-SCHED AS % OF TOTAL	9	13	41
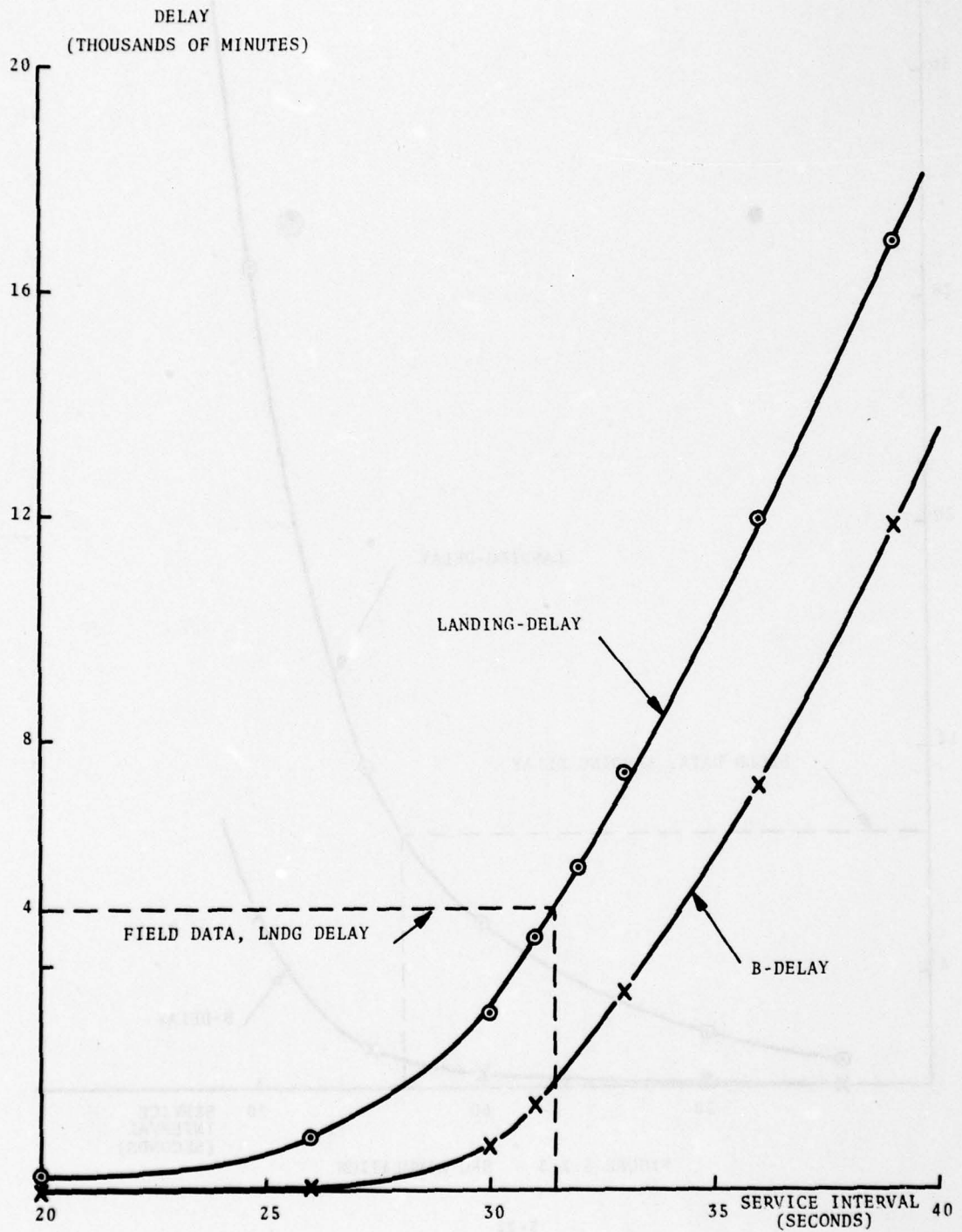
FIGURE 5.2.2 - ORD SIMULATION

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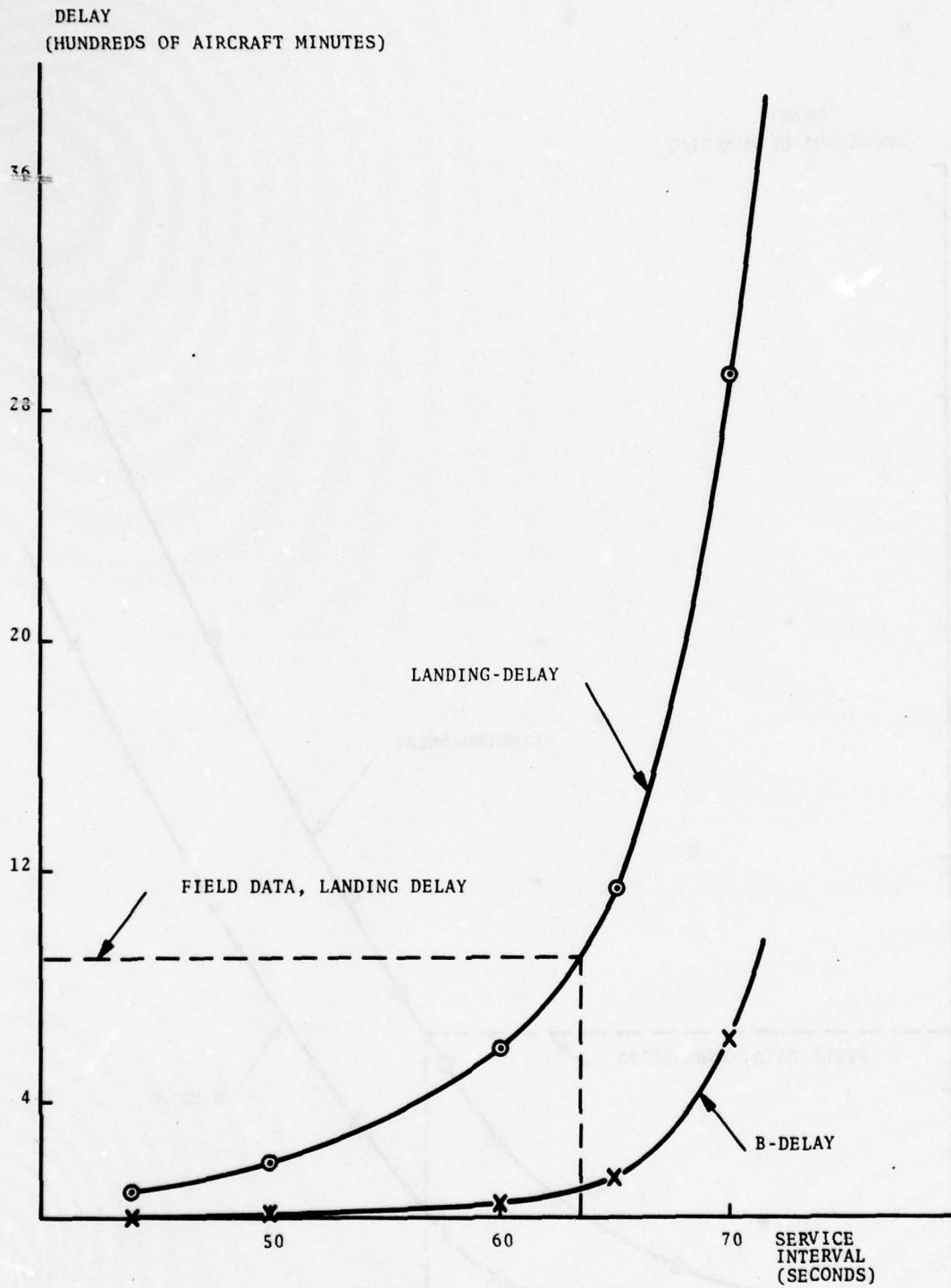
FIGURE 5.2.3 - SFO SIMULATION

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DELAY
(HUNDREDS OF AIRCRAFT-MINUTES)
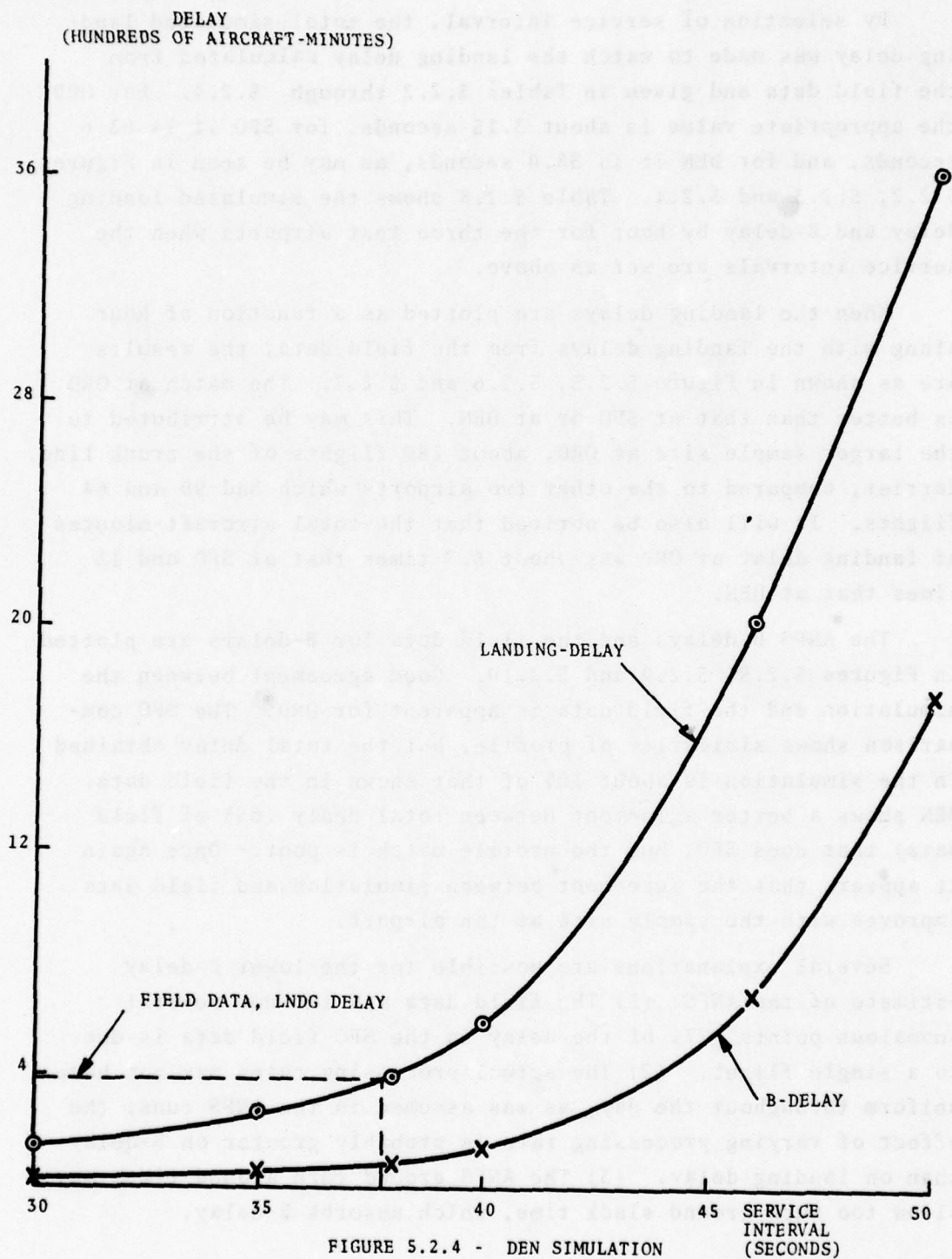
FIGURE 5.2.4 - DEN SIMULATION

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By selection of service interval, the total simulated landing delay was made to match the landing delay calculated from the field data and given in Tables 5.2.2 through 5.2.4. For ORD the appropriate value is about 3.15 seconds, for SFO it is 63.6 seconds, and for DEN it is 38.0 seconds, as may be seen in Figures 5.2.2, 5.2.3 and 5.2.4. Table 5.2.8 shows the simulated landing delay and B-delay by hour for the three test airports when the service intervals are set as above.

When the landing delays are plotted as a function of hour along with the landing delays from the field data, the results are as shown in Figure 5.2.5, 5.2.6 and 5.2.7. The match at ORD is better than that at SFO or at DEN. This may be attributed to the larger sample size at ORD, about 180 flights of the trunk line carrier, compared to the other two airports which had 90 and 64 flights. It will also be noticed that the total aircraft-minutes of landing delay at ORD was about 5.7 times that at SFO and 13 times that at DEN.

The ANFS B-delays and the field data for B-delays are plotted in Figures 5.2.8, 5.2.9 and 5.2.10. Good agreement between the simulation and the field data is apparent for ORD. The SFO comparison shows similarity of profile, but the total delay obtained in the simulation is about 30% of that shown in the field data. DEN shows a better agreement between total dealy (65% of field data) that does SFO, but the profile match is poor. Once again it appears that the agreement between simulation and field data improves with the sample size at the airport.

Several explanations are possible for the lower B-delay estimate of the ANFS: (1) The field data may include several anomalous points; 27% of the delay in the SFO field data is due to a single flight. (2) The actual processing rates may not have uniform throughout the day, as was assumed in the ANFS runs; the effect of varying processing rate is probably greater on B-delay than on landing delay. (3) The ANFS ground turn-around times may allow too much ground slack time, which absorbs B-delay.

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TABLE 5.2.8   SIMULATED LANDING AND B-DELAYS BY HOUR

GMT HOUR	LANDING DELAY (ACFT-MIN)			B-DELAY (ACFT-MIN)		
	ORD	SFO	DEN	ORD	SFO	DEN
12:00	0	0	0	0	0	0
13	15					
14	12			1		
15	318	13	2	0		
16	89	43	28	71		
17	22	33	15	7		
18	275	30	151	4	3	13
19	310	27	17	75	4	42
20	252	112	40	80	0	5
21	274	60	5	108	26	13
22	436	69	4	137	12	0
23	902	47	0	97	14	0
24	465	6	37	344	0	0
25	569	31	45	185	0	0
26	977	94	37	372	2	6
27	202	105	4	300	20	6
28	25	102	0	68	14	2
29	0	101	0	0	11	0
30	0	13	0	0	5	0
31	0	1	0	0	0	0
ANFS	5095	887	391	1852	111	87
DATA	4944	893	383	2343	383	133
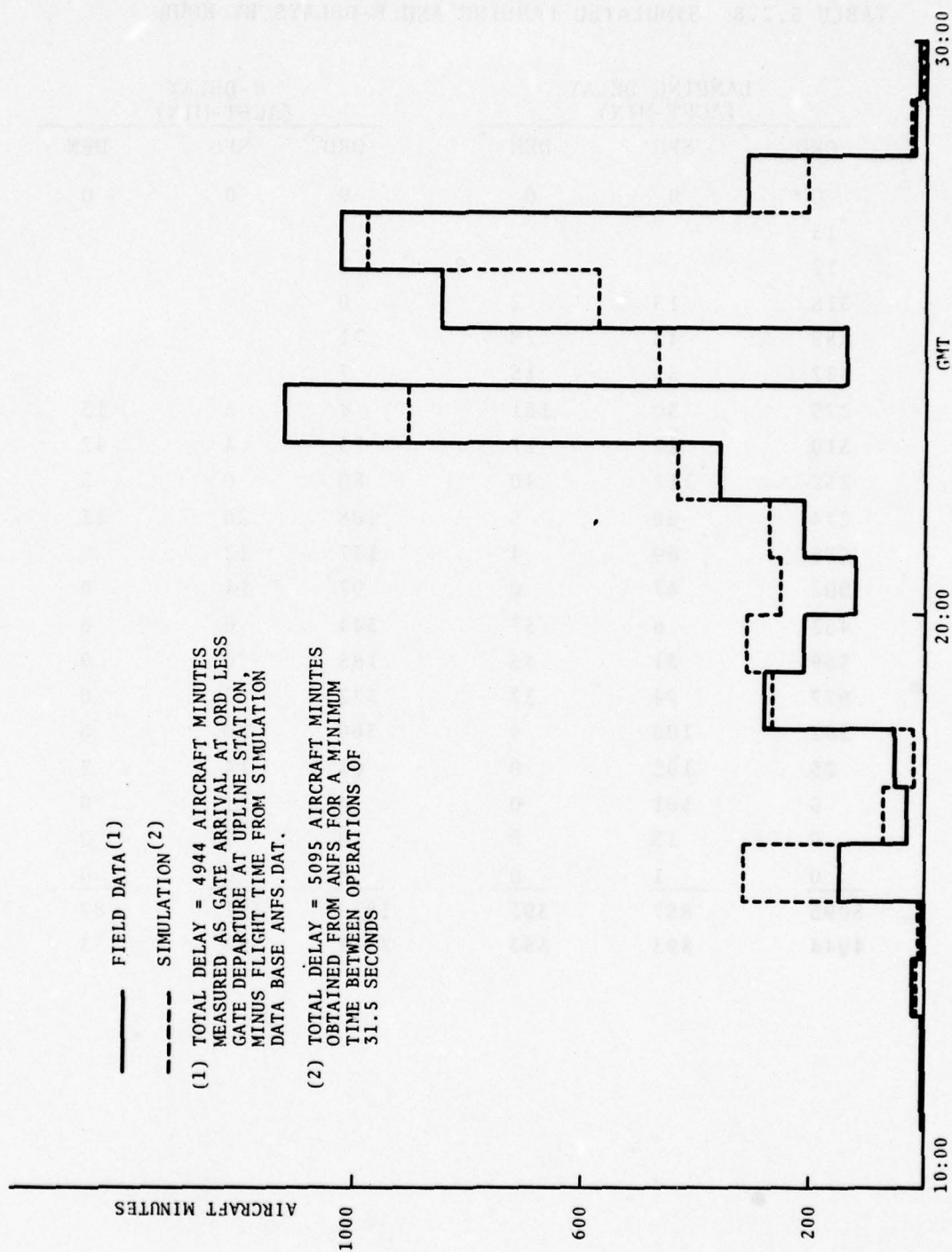
FIGURE 5.2.5 - LANDING DELAY BY HOUR AT ORD - 16 FEB 1976
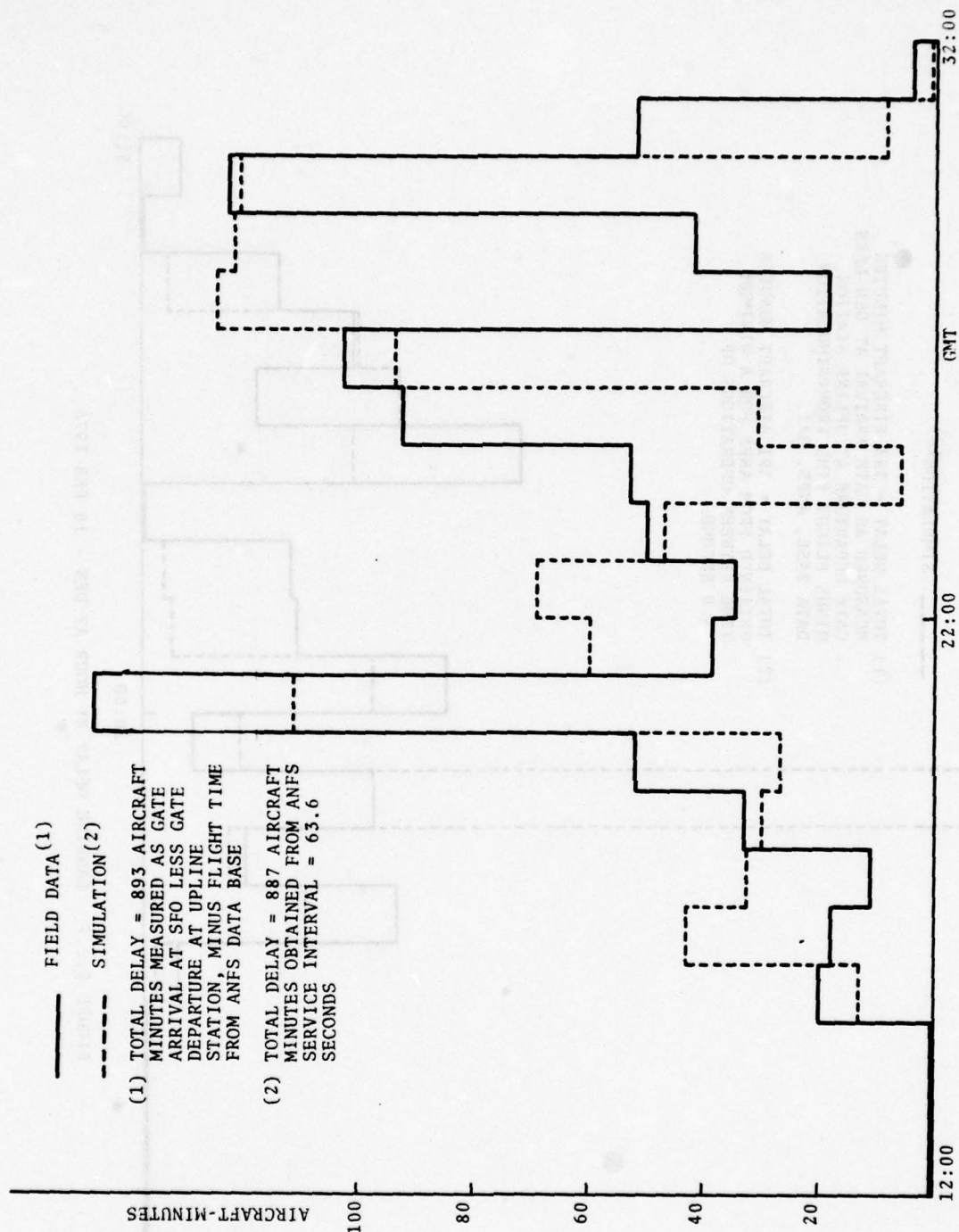
FIGURE 5.2.6 - LANDING DELAY BY HOUR AT SFO - 16 FEB 1976

—— FIELD DATA[1]

---- SIMULATION[2]

(1) TOTAL DELAY = 893 AIRCRAFT
MINUTES MEASURED AS GATE
ARRIVAL AT SFO LESS GATE
DEPARTURE AT UPLINE
STATION, MINUS FLIGHT TIME
FROM ANFS DATA BASE

(2) TOTAL DELAY = 887 AIRCRAFT
MINUTES OBTAINED FROM ANFS
SERVICE INTERVAL = 63.6
SECONDS
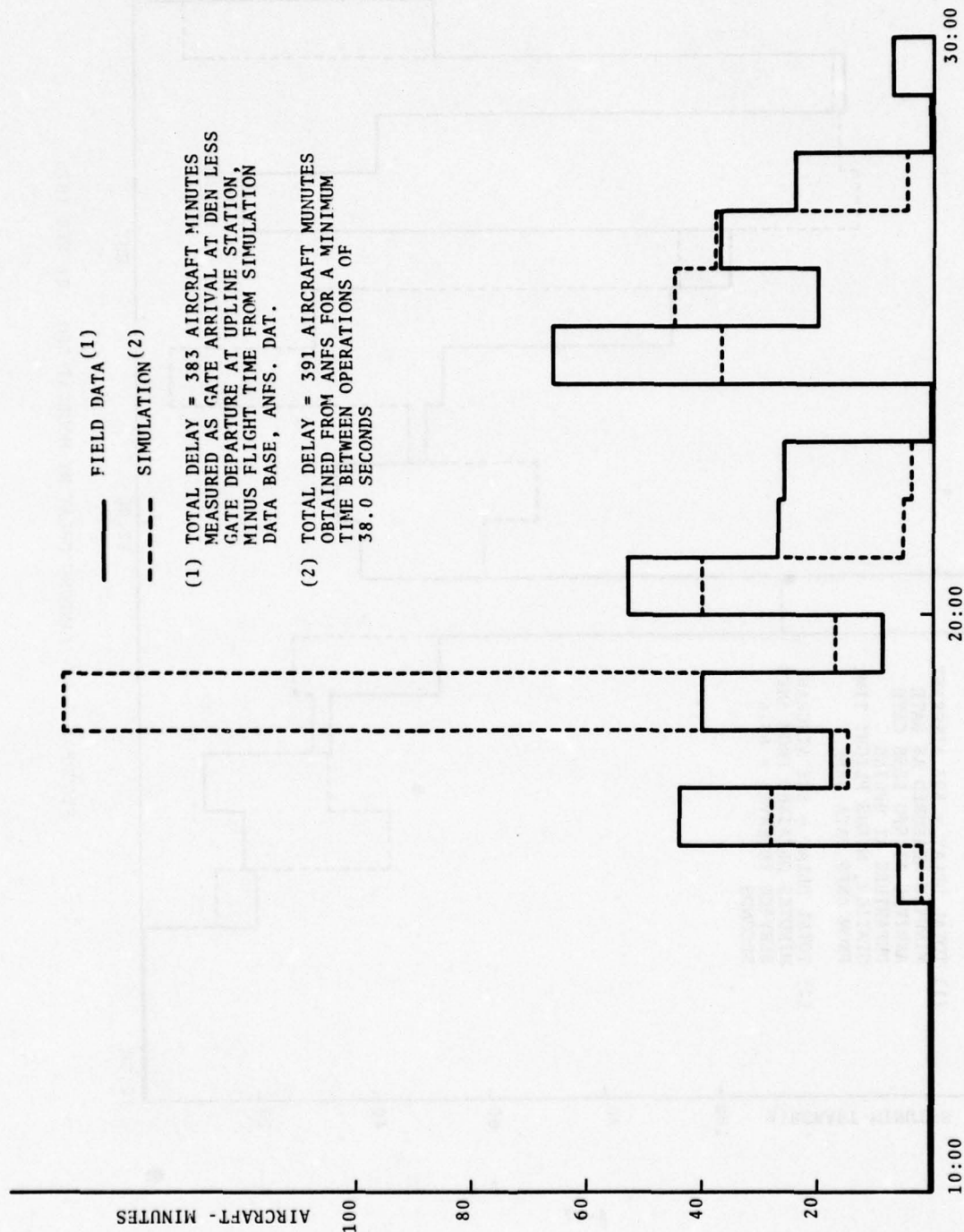
FIGURE 5.2.7 - LANDING DELAY BY HOUR AT DEN - 16 FEB 1976

FIELD DATA[1]

SIMULATION[2]

(1) TOTAL DELAY = 383 AIRCRAFT MINUTES MEASURED AS GATE ARRIVAL AT DEN LESS GATE DEPARTURE AT UPLINE STATION, MINUS FLIGHT TIME FROM SIMULATION DATA BASE, ANFS. DAT.

(2) TOTAL DELAY = 391 AIRCRAFT MINUTES OBTAINED FROM ANFS FOR A MINIMUM TIME BETWEEN OPERATIONS OF 38.0 SECONDS

FIELD DATA[1]

SIMULATION[2]

(1) TOTAL B-DELAY = 2343 AIRCRAFT-MINUTES
DEPARTURE DELAY FOR ORD ORIGINATIONS AND AT
UP-LINE STATIONS REMOVED FROM DATA

(2) TOTAL B-DELAY = 1852 AIRCRAFT-MINUTES
σ=OPERATIONS INTERVAL = 31.5 SECONDS

FIGURE 5.2.8 - B-DELAY BY HOUR AT ORD - 16 FEB 1976

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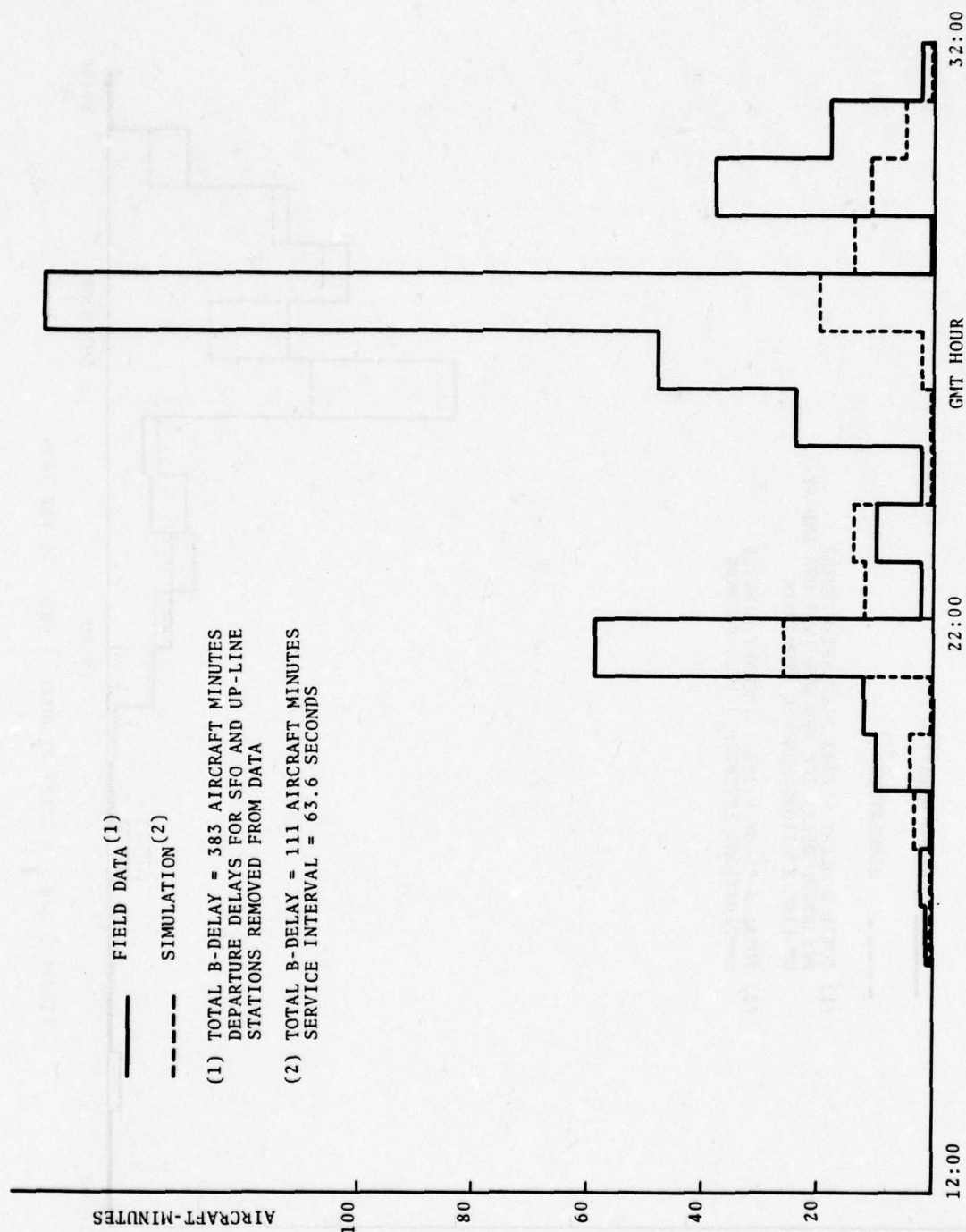
FIGURE 5.2.9 - B-DELAY BY HOUR AT SFO - 16 FEB 1976

FIELD DATA (1)

SIMULATION (2)

(1) TOTAL B-DELAY = 383 AIRCRAFT MINUTES
    DEPARTURE DELAYS FOR SFO AND UP-LINE
    STATIONS REMOVED FROM DATA

(2) TOTAL B-DELAY = 111 AIRCRAFT MINUTES
    SERVICE INTERVAL = 63.6 SECONDS

AIRCRAFT-MINUTES

100

80

60

40

20

10:00　　　　　20:00　　　　　30:00

GMT HOUR

FIELD DATA (1)

SIMULATION (2)

(1) TOTAL B-DELAY = 133 AIRCRAFT-MINUTES. DEPARTURE DELAYS FOR DEN ORIGINATIONS AND AT UP-LINE STATIONS REMOVED FROM DATA

(2) TOTAL B-DELAY = 87 AIRCRAFT-MINUTES. σ=OPERATIONS INTERVAL = 38.0 SECONDS

FIGURE 5.2.10 - B-DELAY BY HOUR AT DEN - 16 FEB 1976

5.2.5 Sensitivity of Simulated B-Delay to Gate Slack

The last of these possibilities was investigated. In order to test the sensitivity of simulated B-delay to aircraft turnaround times, the ANFS was run for fixed runway service times, but different gate slack times. Gate slack time is here defined as the difference between scheduled gate time (i.e., scheduled gate departure, minus scheduled gate arrival) and the minimum gate time required to turn around the aircraft. Simulated landing delay and B-delay are plotted vs. mean gate slack time for the three airports in Figures 5.2.11, 5.2.12 and 5.2.13. The gate slack time shown on the abscissa is the average, in minutes, of the ground slack for all aircraft in the traffic data base (i.e., all aircraft to, from, or through the airport of interest). The parameter KS controls the mean gate slack time (See Section 3.2).

The sensitivity of delays to slack time taken from these Figures is summarized in Table 5.2.9. It is seen that the magnitude of the B-delay per aircraft per minute of slack is greatest at ORD and least at DEN. This suggests that ground time is more tightly scheduled at ORD than DEN, with SFO at an intermediate level. At ORD a minute increase in slack per aircraft will produce about .57 minute decrease in B-delay per aircraft, which indicates that about 57% of the through aircraft at ORD are operating with zero slack at the simulated delay levels.

The mechanism that transfers slack time changes into landing delay changes is more indirect. The slack time increase produces a shift in departure runway demand to earlier time at the airport of interest. If the shifted demand increases the peaking at the airport of interest, an increase in landing delay will result. This occurred, as seen in Table 5.2.9, at ORD and SFO. On the other hand, if the shift in landing demand reduces the peaking, then a reduction in landing delay will occur, as seen in the Table for DEN.

The mean gate slack time may be selected at any one airport to make the simulated B-delays in Table 5.2.8 equal the field data. In doing this, however, the sensitivity of landing delays to

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NOTES: (1) RUNWAY SERVICE INTERVAL = 32.0 SECONDS
(2) LANDING DELAY BASED ON 180 FLIGHTS
(3) B DELAY BASED ON 159 FLIGHTS
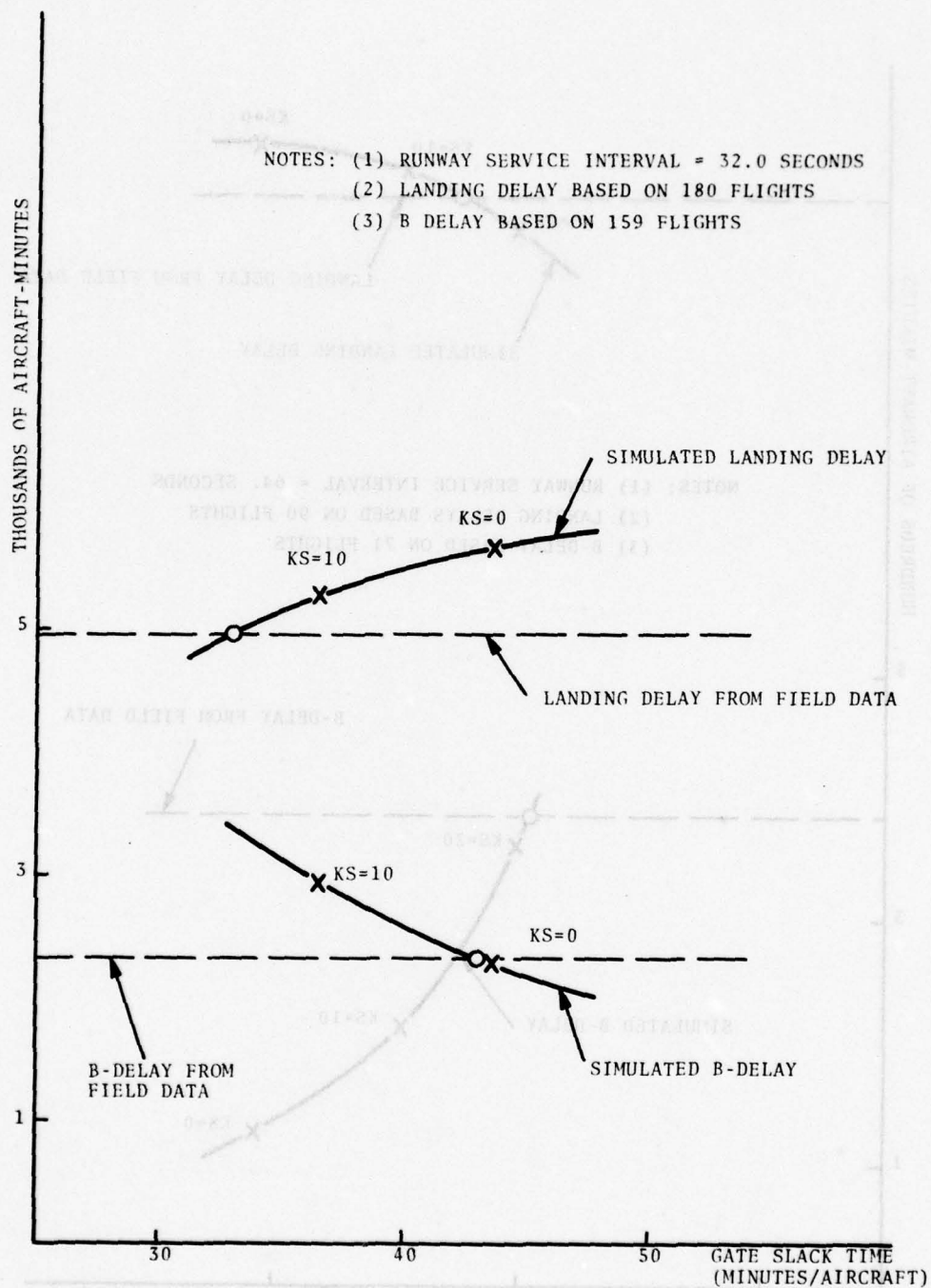
FIGURE 5.2.11 - DELAY VS GATE SLACK TIME, ORD
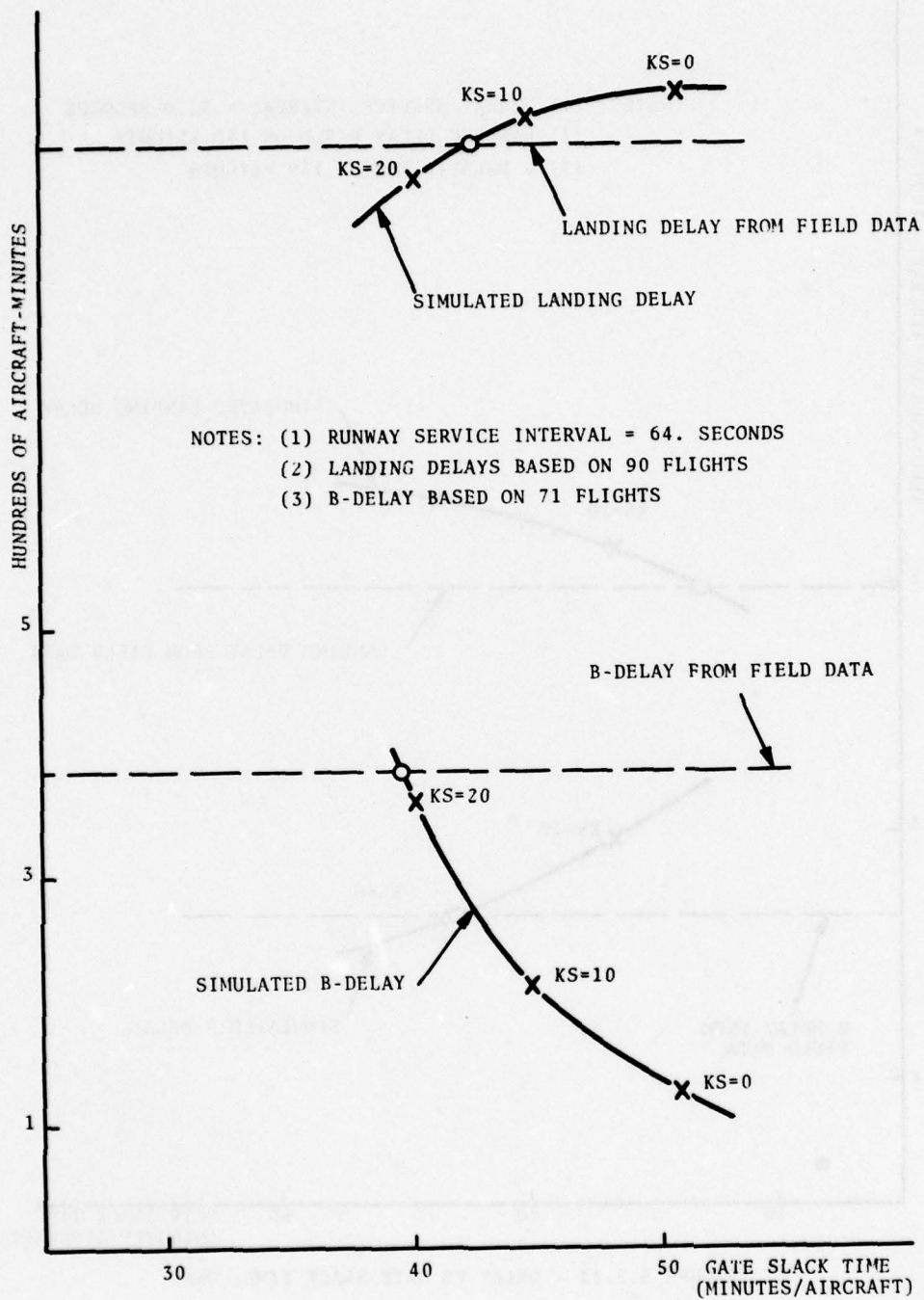
FIGURES 5.2.12 - DELAY VS GATE SLACK TIME, SFO

NOTES: (1) RUNWAY SERVICE INTERVAL = 37. SECONDS
(2) LANDING DELAY BASED ON 64 FLIGHTS
(3) B-DELAYS BASED ON 64 FLIGHTS
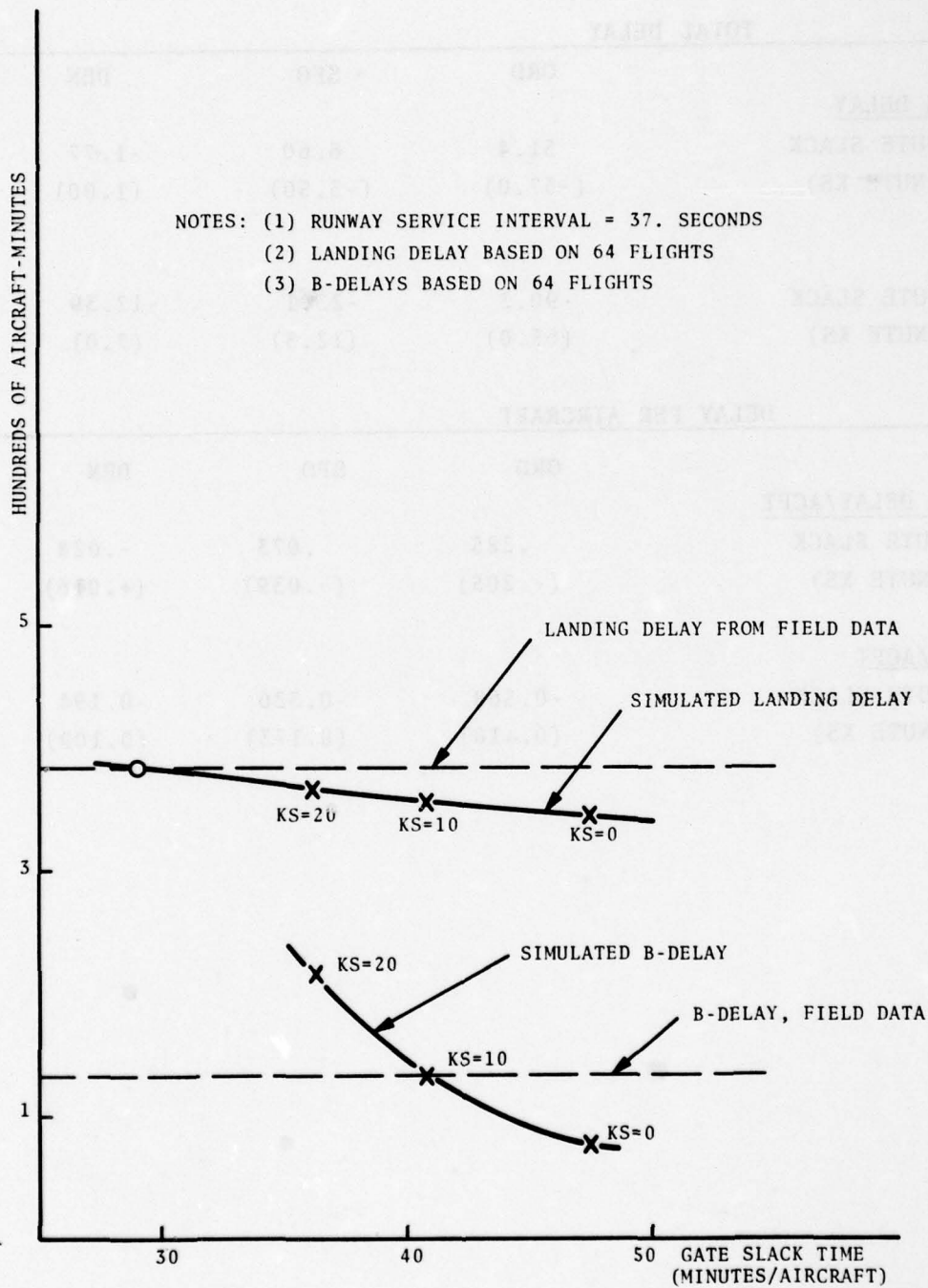
FIGURE 5.2.13 - DELAY VS. GATE SLACK TIME, DEN

TABLE 5.2.9   SENSITIVITY OF DELAYS TO GROUND SLACK TIME

TOTAL DELAY

	ORD	SFO	DEN
LANDING DELAY			
PER MINUTE SLACK	51.4	6.60	-1.77
(PER MINUTE KS)	(-37.0)	(-3.50)	(1.00)
B-DELAY			
PER MINUTE SLACK	-90.3	-23.1	-12.39
(PER MINUTE KS)	(65.0)	(12.3)	(7.0)

DELAY PER AIRCRAFT

	ORD	SFO	DEN
LANDING DELAY/ACFT			
PER MINUTE SLACK	.285	.073	-.028
(PER MINUTE KS)	(-.205)	(-.039)	(+.016)
B-DELAY/ACFT			
PER MINUTE SLACK	-0.568	-0.326	-0.194
(PER MINUTE KS)	(0.410)	(0.173)	(0.109)

changes in service interval σ must be taken into account. In general, the change ΔL in landing delay, and ΔB in B-delay may be related to the change $\Delta\sigma$ in service time and ΔK in slack parameter as follows:

$$\Delta L = \alpha\Delta\sigma + \beta\ \Delta K \tag{1}$$

$$\Delta B = \gamma\Delta\sigma + \delta\ \Delta K \tag{2}$$

The parameters $\alpha, \beta, \gamma, \delta$ were obtained for each airport from Figures 5.2.2-.4 and Table 5.2.9-A. The desired values of ΔL and ΔB were obtained from Table 5.2.8. When equations (1) and (2) were solved, the values obtained for $\Delta\delta$ and ΔK were those shown in Table 5.2.9-B. Only small adjustment are needed in $\Delta\delta$, as expected, while an increment of 7 to 15 minutes is needed in ΔK. Since the ANFS accepts only one K-parameter for all airports, a traffic-weighted average was used for ΔK. Thus

$$\text{KSLACK} = \Delta K = 9.06 \text{ minutes}$$

was obtained as the compromise value. Assuming that the three airports chosen fairly represent all the airports in the system, the value of 9 minutes for the slack parameter may be taken as a permanent adjustment in the ANFS. With this adjustment, the agreement between ANFS and the field data is as shown in Table 5.2.10. The fractional adjustments in the service interval re- quired to make the ANFS landing delay agree exactly with the field data were made by means of Table 5.2.9-A and equation (1), because the simulator input accepts only integer values of the service interval. The corresponding adjustment in B-delay is also shown in the Table. The ANFS error is taken to be the difference between field data B-delay and the adjusted ANFS B-delay, and is shown for the three airports in the last line of the Table. When a traffic-weighted average of the three error magnitudes is taken, the result is 20%, which may be taken as a rough measure of the accuracy of the ANFS B-delay simulation relative to landing delay, when adjustment is made to gate slack time.

TABLE 5.2.9-A CONSTANTS FOR EQUATIONS (1) AND (2)

	ORD	SFO	DEN	
α	1450.	110.	66	$\dfrac{\text{ACFT-MIN}}{\text{SEC}}$
β	-31.	-5.	+1.1~	$\dfrac{\text{ACFT-MIN}}{\text{MIN}}$
γ	900.	88.	16.	$\dfrac{\text{ACFT-MIN}}{\text{SEC}}$
δ	63.	15.	6.7	$\dfrac{\text{ACFT-MIN}}{\text{MIN}}$
ΔL	-151	6.	-8.	ACFT-MIN
ΔB	491.	272.	46.	ACFT-MIN

TABLE 5.2.9-B SOLUTIONS FOR EQUATIONS (1) AND (2)

	ORD	SFO	DEN	
Δσ	.05	.69	-.25	SEC
ΔK	7.1	14.1	7.45	MIN

TABLE 5.2.10   RESULTS OF ANFS B-DELAY VALIDATION

	ORD	SFO	DEN	UNITS
LANDING DELAY				
SAMPLE SIZE	180	90	65	AIRCRAFT
KSLACK	9	9	9	MINUTES
ADJUSTED SERVICE INT'V'L	31.73	63.72	37.40	SECONDS
ADJUSTED ANFS DELAY	4944.	893.	383	ACFT-MIN
FIELD DATA DELAY	4944	893	383	ACFT-MIN
B-DELAY				
SAMPLE SIZE	159	71	60	AIRCRAFT
KLSLACK	9	9	9	MINUTES
ADJUSTED SERVICE INT'V'L	31.73	63.72	37.40	SECONDS
ADJUSTED ANFS DELAY	2622.	177.	130.	ACFT-MIN
FIELD DATA DELAY	2343	383	133	ACFT-MIN
ERROR	12	-54	-2	PERCENT

5.3 SUMMARY

The linkages of single OAG flight legs produced by the ANFS schedule generator was found to be 94% in agreement with actual airframe linkages for one day, as obtained from a large trunk line carrier. But when complete aircraft itineraries were compared with complete itineraries obtained from a second trunk line carrier, an estimate of 70% correctness was obtained.

Next, the B-delays produced by the ANFS were compared to B-delays extracted from the data of the second carrier and found to be within 12% for ORD, 54% for SFO and 2% for DEN, giving a weighted average error of 20%. This comparison of B-delays is based on (1) adjusting the ANFS runway service intervals at the three air-ports so that the simulated landing delays agree with those obtained from the data, and (2) a permanent adjustment in the ANFS ground slack time parameter.

REFERENCES

(1) Gordon, Steven, "The Airport Network Flow Simulator," Report No. FAA-ASP-75-6, U.S. Department of Transportation, Transportation Systems Center, Cambridge MA. Interim Report, May 1976.

(2) U.S. Department of Transportation, Federal Aviation Administration, "The National Aviation System, Challenges of the Decade Ahead, 1977-1986."

(3) U.S. Department of Transportation, Federal Aviation Administration, "Profiles of Scheduled Air Carrier Airport Operations, TOP 100 U.S. Airports," 1976.

(4) U.S. Civil Aeronautics Board, Economic Evaluation Division, Bureau of Accounts and Statistics, "Aircraft Operating Cost and Performance Report, Fiscal 1974," February 1975, Washington, D.C.

(5) Federal Aviation Administration, "General Aviation Cost Impact Study," Report DOT-FA-72WA-3118, Final Report, prepared by Batelle-Columbus Laboratory, Columbus, Ohio, June 1973.

(6) Munt, R., E. Danielson and J. Daimen, "Aircraft Technology Assessment: Interim Report on the Status of the Gas Turbine Program," U.S. Environmental Protection Agency, Washington D.C., 1975.

(7) U.S. Department of Transportation, Federal Aviation Administration, Selected Statistics of Published Domestic Air Carrier Schedules, Vol. IV: Estimated Flight Loads, March 1974, pp. 32-55, prepared by Potomac Scheduling Company.

APPENDIX A: SUMMARY OF FIELD DATA
ON B-DELAY[1]

Data were collected from two carriers, a large U.S. trunk line carrier and a local service carrier. These data contained scheduled and actual times of gate departure and arrival for all aircraft of the carrier on a single day. This Appendix describes how the data were analyzed in order to obtain estimates of A-delay (landing delay) and B-delay (gate departure lateness).

LOCAL SERVICE CARRIER

The data for this carrier covered service on December 9, 1975. The data were analyzed to obtain an estimate of the relative magnitude of Type-A and Type-B delays. The results are presented in Table A-1. Type-A delay presented in Table A-1 is defined as the difference between actual and scheduled flight durations. Type B-delay presented in Table A-1 is defined as the difference between actual and scheduled departure times.

The Type-A delay may be understated because schedules may include some slack. To estimate the slack in schedules, use was made of the mean nonpositive delay. This is the average "earli-ness" of flights that arrived on time or early. For the most part, these are flights that encountered little or no Type-A delay. Adjusting for the average slack in schedules, the average Type-A delay amounted to 3.59 minutes. Although the average Type-B delay amounts to 13.89 minutes, this includes some negative Type-B delay--caused by flights departing before schedule. This arises when the aircraft is full or when all passengers with reservations arrive early. It does not make sense to count these early departures as offsets against Type-B delay. Consequently, Type-B delay was recomputed assuming that negative observations are in effect zero. This results in an average Type-B delay of 14.11 minutes.

Some lateness in departure is due to machanical diffi-culties, loading of baggage, or anticipation of Type-A delay.

(1)The work described in this Appendix was performed under Contract DOT-TSC-1184, carried out by Simat, Helliesen and Eichner, Newton Centre, MA.

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The amount of such lateness is estimated by considering only the lateness in depature for each aircraft of the first flight leg of the day. This delay of 4.38 minutes cannot be true Type-B delay. Consequently, after adjusting for this factor, the average Type-B delay is 9.28 minutes, which is more than twice the Type-A delay. Even if all of the 4.38 minutes represented gate delay taken in anticipation of flight delays (for example, because of flow control procedures), then Type-A delay would amount to 8.42 minutes--still less than Type-B delay. This analysis shows that even under conservative conditions (underestimation of Type-B and overestimation of Type-A delays), Type-B delays exceeded Type-A delays on December 9, 1975, for this particular local service carrier. This conclusion fails to generalize, of course, to other carriers or to other days.

TRUNK LINE CARRIER

The data for the trunk line carrier covered its flights on February 16, 1976. They were analyzed according to the techniques employed for the local service carrier data. Table A-2 presents the results of this analysis. As before, the best estimate of real (but unobservable) Type-A delay is given by line 1 minus line 4, or 10.39 minutes/flight. Similarly, the best estimate of real Type-B delay is given by line 5 minus line 9, or 5.06 minutes/flight. The delays, once again, are of the same order of magnitude as those for the local service carrier, even though the day analyzed was not a terribly poor one. However, the trunk line carrier's Type-B delays are less than its Type A-delays, as contrasted to the local service carrier's Type-B delays, which are greater than its Type-A delays. This result is expecte and due to longer average length of haul of the trunk line. Table 2 was constructed after deleting two outlying points corresponding to Type-B delays of 244 and 350 minutes. The most likely explanations of these points are that they represent errors in the data or the operation of flights that would have been cancelled had they not been required to transport the flight crew or the aircraft to some other point.

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TABLE A-1

ANALYSIS OF DELAYS OF LOCAL SERVICE
AIRCRAFT ON DECEMBER 9, 1975

TYPE OF OBSERVATION (1)	NUMBER OF OBSERVATIONS (2)	MEAN (MINS.) (3)	STANDARD DEVIATION (MINS.) (4)
1. Type-A Delays	300	1.45	4.55
2. Negative Type-A Delays	100	-3.04	2.08
3. Zero Type-A Delays	42	0.00	0.00
4. Nonpositive Type-A Delays	142	-2.14	2.23
5. Type-B Delays	300	13.89	26.41
6. Negative Type-B Delays	21	-3.14	1.98
7. Zero Type-B Delays	69	0.00	0.00
8. Type-B Delays with Negative Delays Counted as Zero	300	14.11	26.28
9. Type-B Delays for Aircraft on First Flight Leg of Day	30	4.83	9.59

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TABLE A-2

ANALYSIS OF DELAYS OF TRUNK LINE
AIRCRAFT ON FEBRUARY 16, 1976
(EXCLUDING OUTLYING DATA POINTS)

TYPE OF OBSERVATION (1)	NUMBER OF OBSERVATIONS (2)	MEAN (MINS.) (3)	STANDARD DEVIATION (MINS.) (4)
1. Type-A Delays	1419	5.88	14.73
2. Negative Type-A Delays	474	-5.42	5.24
3. Zero Type-A Delays	96	0.00	0.00
4. Nonpositive Type-A Delays	570	-4.51	5.19
5. Type-B Delays	1417	7.55	17.56
6. Negative Type-B Delays	54	-6.41	11.16
7. Zero Type-B Delays	690	0.00	0.00
8. Type-B Delays, with Negative Delays Counted as Zero	1417	7.88	17.28
9. Type-B Delays for Aircraft on First Flight Leg of Day	317	2.49	6.73

Passengers would probably not experience these long delays, instead seeking service on other carriers, later flights, or alternate routes. Table A-3 presents the results including the two outlying points. Note that the standard deviation of line 9 is much higher in relation to the mean of line 9 and the standard deviation of line 5 than one would expect based on the local service results. Such is not the case when the outlying points are omitted, as shown in Table 2. Based on this observation and on the preceding discussion, it appears that Table 2 is more appropriate than Table 3 for drawing conclusions as to the relative magnitude of Type-A and Type-B delays for the trunk line carrier.

SUMMARY

The results described above are summarized in Table A-4.

TABLE A-3.

ANALYSIS OF DELAYS OF TRUNK LINE
AIRCRAFT ON FEBRUARY 16, 1976
(INCLUDING OUTLYING DATA POINTS)

TYPE OF OBSERVATION (1)	NUMBER OF OBSERVATIONS (2)	MEAN (MINS.) (3)	STANDARD DEVIATION (MINS.) (4)
1. Type-A Delays	1419	5.88	14.73
2. Negative Type-A Delays	474	-5.42	5.24
3. Zero Type-A Delays	96	0.00	0.00
4. Nonpositive Type-A Delays	570	-4.51	5.19
5. Type-B Delays	1419	7.96	20.74
6. Negative Type B-Delays	54	-6.41	11.16
7. Zero Type-B Delays	690	0.00	0.00
8. Type-B Delays, with Negative Type-B Delays Counted as Zero	1419	8.21	20.49
9. Type-B Delays for Aircraft on First Flight Leg of Day	318	3.58	20.61

TABLE A-4

SUMMARY OF A- AND B-DELAYS

	LOCAL SERVICE CARRIER	TRUCK LINE CARRIER
DATE OF DATA	12/9/75	2/16/76
NUMBER OF DEPARTURES	300	1419
A-DELAY PER DEPARTURE	3.6 MIN	10.4 MIN
B-DELAY PER DEPARTURE	9.3 MIN	5.1 MIN
RATIO OF B-DELAY/A-DELAY	2.58	0.49

APPENDIX B: PROGRAM LISTINGS

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BDL BDR ORD ATL JFK LGA SFO LAX DEN PHL EWR MIA DAL DCA PIT BOS CLE DTW MSY LAS
HNL STL FLL TPA MSP SEA BAL CLT MKE SLC IAH IAD JAX DFW HVN GON HFD RKD PWM BGR
PQI LEW AUG WVL BHB PSF ORH BED ACK HYA MVY EWB PVC LWM MHT EEN LEB HIE LCI PVD
BID WST NPT BTV RUT MPV VSF TTN AIY WWD MMU ARX TEB BUF ROC ALB SYR ISP HPN ITH
UCA BGM ELM JHW ART IPT MDT ABE AVP ERI BFD PNE RDG LNS MSS OGS GFL PLB SLK HZL
FKL DUJ PSB AOO JST POU HAR SCE ONH MSV JRB FRG ILG FYN MTL MCO PBI MLB DAB PNS
SRQ TLH GNV FMY AGS SAV CSG MCN SSI PGD VRB ORL TIX OCF MRK PFN APF VPS HGR SBY
ESN CBE ODM ABY YLD MGR AHN CWG GSO SDU AVL HKY INT FAY ISO ILM OAJ EWN RMI HNC
MEO SOP CAE CHS GSP HHH GRD FLO AND MYR ECG MRH PGV RIC ORF PHF WOU CHO SHD LYH
ROA FRQ HSP DAN WGO CRW PKB HTS CKB MGW EKN BKW LWB BLF DNV PIA MDW CGX MLI UIN
SPI CMI BMI MTO MVN GBG SQI MWA IND MIE HUF BMG EVV FWA PLY SBN DEC RFD MGC VPZ
WMS ALN MDH DET AZO GRR CMX MQT LAN SVC PTK IMT IND MNM ESC JXN FNT CMH DAY CVG
CAK TOL YNG MFD BKL OSU GQQ MBS BEH PLN MBL ISW MFI STE EAU ASX HYR SBM SUE CWA
MSN GRB JVL MTW OSH RHI LSE SSM APN MKG MQB LIA PHN ATW BTL PKI LAF OKK BHM MGM
HSV MOB TCL MSL DHN ANB GAD AUO SDF LEX PAH OWB BWG FFT LOZ HEZ JAN GPT MEI PIB
HKS GTR GLH TUP GWO UOX BNA MEM TYS CHA TRI CKV CSV PHT MKL BRL CID ALO DSM SPW
WUK SUX DBQ OTM MCW FOD EOK FMS CWI ICT LBL MHK TOP SLN GCK GLD HYS PPF LWC EMP
GBD HUT OJC DDC DLH RST HIB INL FRM MKT OTG BJI BRD TVF ULM STP ONA EVM IRK MCI
MKC SGF JLN TBN CGI COU POF KNT MAW GPZ JEF DMO OMA LNK GRI AIA BFF SNY CDR EAR
MCK HSI OLU LBF OFK AIZ BLA RIS MOT FAR GFK IAN DVL JMS RAP FSD HON MHE YKN ABR
ATY PIR BKX LIT FSM HOT FYV HRO PBF TXK FLD JBR SHV BTR ESF MLU NEW LFT POE LCH
DRI OKC TUL LAW WDG WLC PNC AXS ELP SAT AUS CRP BRO AMA LBB MAF SPS BPT ABI PRX
HOU LFK OCH GGG TYR CLC GLS LJN VCT PSN SJT MWL ACT TPL HCA BWD LRD HRL MFE ILE
DRT CLL PHX TUS YUM INW GCN PGA FLG IGM LHU PRC ASE COS PUB GJT CEZ DRO ALS LAA
GUC MTJ HDN LXV EGE SBS LWS BOI WAU MPB SUN PIH TWF WCI GNY FTC IDA BZN MSO FCA
BIL GTF MLS GDY SDY LWT GGW OLF HVR BTM HLN LOL RNO WMC EKO ELY ABQ GUP FMN ALM
SVC ATS ROW RUI CNM HOB CVN SAF RTN TSM WGS VEL BMC TRT LGU OGD PUC CNY WBT WUO
BDG WUJ CDC SGU MLF EAN CYS ECS SHR RKS RWL CPR RIW WRL COD JAC LAR GCC SAA WJA
DGW DTA RIF LRU SAN PSP OAK ONT SJC BUR CKE STS NOT PAO UKI FOB LVR PDX LMT WFB
MFR LGB SMF WYK AVX TWH SNA OXR SBA PMD IYK WIX GEG YKM PUW ALW PSC EAT RLD PWT
BFI OLM TIW HQM MHV FUL RAL ODW BLI AST IPL ACV EKA CEC CIC RBL MYV COA RDD OVE
TVL JEM JMC OBR FAT SCK BKE LGD BLE SDM WBH WBY EUG BFL SMX OTH BLH MRY MMH BIH
PDT MOD MCE VIS MWH SRF CCR APC VLO SBP PRB CLM WCG WCF WBV YUL YYZ ADQ ENA AKN
JNU FAI ANC SJU OUT
```

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 5   5   6   5   5   5   8   8   7   5   5   5   6   5   5   5   5   5   6   8
10   6   5   5   6   8   5   5   6   7   6   5   5   6   5   5   5   5   5   5
 5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5
 5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5
 5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5
 5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   6
 5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   6   5   6   5   5
 5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5
 5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5
 6   6   6   6   6   6   6   5   5   5   6   5   5   5   5   6   6   6   6   6
 6   6   6   6   6   6   6   5   5   5   6   6   6   6   6   6   6   6   6   6
 5   5   5   5   5   5   5   5   6   5   6   6   6   6   6   6   6   6   6   6
 6   6   6   6   6   6   5   5   5   6   6   5   6   6   6   6   5   5   6   6
 6   6   6   6   6   6   6   6   5   5   5   6   6   6   6   6   6   6   6   6
 6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   7   6   6   6   6
 6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
 6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   7   7   7   7   6
 6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
 6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   7   7   7   7   6
 6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
 6   6   6   6   6   6   6   7   6   6   6   6   6   6   6   6   6   6   6   6
 6   6   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7
 7   7   7   7   7   7   7   8   7   7   7   7   7   7   7   7   7   7   7   7
 7   7   7   7   7   7   7   7   7   8   8   8   8   8   8   7   7   7
```

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  7   7   7   7   7   7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7
  7   7   7   7   7   7  7  7  7  7  7  7  7  7  7  7  7  7  7  7  7
  7   7   7   7   8   8  8  8  8  8  8  8  8  8  8  8  8  8  8  8  8
  8   8   8   8   8   8  8  8  8  8  8  8  8  8  8  8  8  8  8  8  8
  8   8   8   8   8   8  8  8  8  8  8  8  8  8  8  8  8  8  8  8  8
  8   8   8   8   8   8  8  8  8  8  8  8  8  8  8  8  8  8  8  8  8
  8   8   8   8   8   8  8  8  8  8  8  8  8  8  8  8  8  5  5 10 10 10
  8  10  10   4  99
        5402      38222
    5 51300 21420  173
    8 72720  1740  173
    8 76500 14760  173
   17 91260  1860  173
   17 93300  3060  173
   75 96360 43201  173
    8 60300 17460  165
    5 78120 43201  165
  565 60000  2100  173
    8 62100  1740  173
    8 63900 17520  173
   11 81480  2040  173
   11 93600  4320  173
   32 97920     0  173
   32 98580 11820  173
   34110400  1800  173
   34112200 10380  173
    8123360 43201  173
   34 25800 10380  173
    8 36960  1740  173
    8 63000 14760  173
   17 77760  1860  173
   17 80100  3060  173
   75 83160  2340  173
   75 85500  3840  173
    5 89340 43201  173
  565 58500  2220  165
    8 60780  1920  165
    8 63600 17640  165
   16 81240  2700  165
   16 85800  9000  165
    3 95400  2700  165
    3 98100 12900  165
  463111000  2400  165
  463113400  6300  165
    7119700 43201  165
    7 59400 18300  165
    5 78000  3660  165
    5 82800 21000  165
    8104160 43201  165
    7 72000 18300  165
    5 90660 43201  165
    5 61200 21900  165
    7 83220  3180  165
    7109200  5820  165
  463115020  2400  165
  463117600 10620  165
    3128220 43201  165
  463 31200 10620  165
    3 41820  2700  165
    3 46800  4800  165
  657 51600  7200  165
```

B-3

APPENDIX B-2. CAPACITY DATA, CAPCTY.DAT

First page: General sample of CAPCTY.DAT
             file

Second page: Special form of CAPCTY.DAT for
             JFK test case.

	100			10			60			09														
ORD	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
9	1	1	1	1	1	1	1	5	6	6	5	6	6	6	7	7	7	6	4	2	1			
JFK	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
8	3	1	2	2	1	1	2	3	4	5	4	3	4	3	4	7	7	8	8	7	6	7	4	3
SFO	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
13	2	1	0	0	1	1	2	4	5	6	5	5	5	6	6	6	3	5	6	7	7	5	3	3
ALL	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

```
        100     10     60      09
JFK   60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60 60
       8  3  1  2  2  1  1  2  3  4  5  4  3  4  3  4  7  7  8  7  6  7  4  3
ALL   00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
       0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```

APPENDIX B-3.   COST DATA PROGRAM, COST.F4

```
      OPEN(UNIT=6,DEVICE='DSK',ACCESS='SEQOUT',FILE='COST.DAT')
      INTEGER PCOST,TCOST(100),LCOST(100),LOAD(32,100),LOAD0(100),
     1HFACT(32,24),HFACT0(24),STK(16),SLS(8),SIS(13),BOARD(32),
     2SIF(91),SCT(147),SHO(26),AC3LC(100),ACSEB(100),BOARD0
      DATA PCOST/1250/
      DATA TCOST/          8863, 33989,  3967,  3967,  3967,  9883,  8863,
     1  3967,  8863,  8863,  1317, 33989, 26829, 26829, 33989, 33989,
     2 26829, 26829, 71183,  3967, 26829,  8863, 33989, 33989,  1317,
     3  3967, 92952, 92952, 33989,  8863, 33989,  3967,  8863,  1317,
     4 71183, 33989,  3967,  3967, 26829,  3967,  8863, 33989,  8863,
     5     0,     0,  3967,  8863, 33989, 71183, 92952,  8863,     0,
     6  3967, 33989,  1317,  1317,  1317,     0,     0, 49467, 39393,
     7 56629, 56629, 39393, 69127, 56629, 39393, 39393, 39393, 69127,
     8 39393, 54495, 56629, 46944, 54495, 46944, 39393, 39393, 88787,
     9 88787, 54495, 54495, 56629, 88787, 39393,1500/
      DATA LCOST/          9676, 38927,  4760,  4760,  4760,  6348,  9676,
     1  4760,  9676,  9676,  1581, 38927, 29413, 29413, 38927, 38927,
     2 29413, 29413, 78423,  4760, 29413,  9676, 38927, 38927,  1581,
     3  4760,102724,102724, 38927,  9676, 38927,  4760,  9676,  1581,
     4 78423, 38927,  4760,  4760, 29413,  4760,  9676, 38927,  9676,
     5     0,     0,  4760,  9676, 38927, 78423,102724,  9676,     0,
     6  4760, 38927,  1581,  1581,  1581,     0,     0, 67808, 50062,
     7 80704, 80704, 50062,107500, 80704, 50062, 50062, 50062,107500,
     8 50062, 75000, 80704, 62500, 75000, 62500, 50062, 50062,147203,
     9147203, 75000, 75000, 80704,147203, 50062, 1500/
C LOAD0(I,J) IS AVG NUMBER OF PAX DEPARTING ON ACFT TYPE J AT APT I.
      DATA (LOAD(1,J),J=1,100)/9*0,4,4*0,28,7*0,19,37*0,37,73,79,45,88,
     1 89,57,0,0,77,0,0,76,69,0,6,63,0,59,0,100,76,19*0/
      DATA (LOAD(2,J),J=1,100)/22*0,42,5*0,16,18*0,17,13*0,42,91,46,91,7
     1 18,60,0,0,79,0,0,0,75,0,65,0,42,0,102,20*0/
      DATA (LOAD(3,J),J=1,100)/60*0,30,65,88,0,99,71,39,0,0,107,0,0,24,6
     1 18,0,71,0,49,0,142,20*0/
      DATA (LOAD(4,J),J=1,100)/22*0,12,37*0,48,0,0,48,99,0,84,0,0,67,0,
     1 18,0,78,0,64,0,59,22*0/
      DATA (LOAD(5,J),J=1,100)/14*0,44,8*0,19,37*0,76,55,91,100,81,33,0,
     1 18,100,0,0,76,47,55,52,0,36,0,156,82,19*0/
      DATA (LOAD(6,J),J=1,100)/23*0,18,3*0,8,33*0,79,62,55,84,116,46,0,8
     1 1,89,0,0,76,38,65,60,0,47,0,125,20*0/
      DATA (LOAD(7,J),J=1,100)/14*0,18,6*0,5,39*0,79,75,39,69,77,39,5*0,
     1 171,52,69,62,46,47,0,0,0,66,19*0/
      DATA (LOAD(8,J),J=1,100)/6*0,5,0,0,22,4*0,20,6*0,5,8*0,15,29*0,43,
     1 146,91,58,67,95,53,0,0,76,0,0,66,69,0,52,0,57,22*0/
      DATA (LOAD(9,J),J=1,100)/9*0,18,4*0,40,6*0,3,38*0,42,95,75,50,101,
     1 89,64,0,0,84,0,0,83,63,0,64,0,57,0,73,19*0/
      DATA (LOAD(10,J),J=1,100)/61*0,18,64,62,73,33,57,0,0,81,3*0,57,56
     1 1,51,3*0,118,20*0/
      DATA (LOAD(11,J),J=1,100)/100*0/
      DATA (LOAD(12,J),J=1,100)/6*0,14,0,0,20,4*0,23,7*0,19,7*0,16,16*0,
     1 122,12*0,41,0,0,37,0,0,78,6*0,66,0,70,0,49,22*0/
      DATA (LOAD(13,J),J=1,100)/9*0,4,4*0,23,6*0,3,3*0,46,60,0,46,49,46
     1 1,52,0,0,65,0,0,55,46,0,51,0,45,0,75,39,19*0/
      DATA (LOAD(14,J),J=1,100)/14*0,29,7*0,15,37*0,45,56,80,47,118,88,6
     1 11,0,0,73,0,0,84,71,0,61,0,77,0,89,76,19*0/
      DATA (LOAD(15,J),J=1,100)/14*0,33,11*0,2,33*0,47,0,72,49,81,62,60,
     1 15*0,70,51,0,57,0,58,0,99,20*0/
      DATA (LOAD(16,J),J=1,100)/14*0,24,45*0,40,40,76,0,84,98,46,0,0,69,
     1 18,0,72,62,0,70,0,70,0,111,20*0/
      DATA (LOAD(17,J),J=1,100)/15*0,23,12*0,1,33*0,65,27,61,62,48,0,0,5
     1 14,3*0,56,0,51,24*0/
      DATA (LOAD(20,J),J=1,100)/14*0,14,7*0,11,37*0,51,45,0,38,0,0,44,0,
     1 18,81,0,0,65,57,0,59,41,3*0,72,19*0/
```

```
C  MFACTS IS AVG OF MSY, STL, TPA, MSP, SEA, IAH
      DATA (MFACTS(J),J=1,24)/57,30,19,22,25,19,63,94,132,135,163,166,15
     17,138,132,148,154,168,151,132,184,66,63,63/
C  SCHEDULED TRUNKLINES
      DATA STK/'AA','BN','CO','DL','EA','NA','NW','TW','UA','WA'/
C  SCHEDULED LOCAL SERVICE CARRIERS (PLUS NE)
      DATA SLS/'AL','FL','NC','NE','OZ','PI','RW','SO','TI'/
C  SCHEDULED INTRA-STATE CARRIERS
      DATA SIS/'AS','HA','JE','KO','OC','PS','QM','QX','RV','TS','WC','
     1WN','XY'/
C  SCHEDULED INTERNATIONAL, TERRITORIAL AND FOREIGN FLAG CARRIERS
      DATA SIF/'AC','AF','AM','AT','AV','AZ','BA','BH','BL','BT','BW','
     1CO','CI','CP','CU','DO','EM','FG','GU','GX','HP','HS','MU','IB','
     2JH','JL','JM','JO','JQ','JR','JS','JE','KI','KL','KX','LA','LH','
     3LI','LM','LR','MX','ND','NK','NN','NR','OA','OO','OG','OP','PA','
     4PO','PL','PN','PR','PV','PW','PY','QB','QF','QQ','SH','SK','TE','
     5TZ','UM','UP','UW','VA','VG','VY','WM','WS','WY','YB','ZC','AI','
     6AR','AY','DG','ES','IN','IR','KE','LL','LY','NI','RG','SN','SR','
     7TP','TX/
C  SCHEDULED COMMUTER/TAXI CARRIERS (DEC 75 OAG + AP AND FW)
      DATA SCT/'AG','IA','AK','AP','BF','BK','CB','CG','CJ','CT','CZ','
     1DD','DE','DF','DH','DI','DK','DN','DP','EB','EE','EJ','EV','EZ','
     2FJ','FE','FH','FN','FP','FS','FW','FY','FZ','GE','GM','GO','GW','
     3HG','HI','HO','HP','HQ','HW','HY','IO','II','IK','IU','JB','JC','
     4JI','JV','JH','KF','KG','KJ','KN','KW','LS','MF','MI','MJ','NF','
     5NP','NQ','NT','OP','OO','OQ','OW','OX','OY','PE','PF','PH','PP','
     6PQ','PT','QA','QG','QS','QT','RL','RX','SF','SL','ST','SZ','
     7TB','TJ','UD','UM','UO','UQ','UR','US','UV','UX','VB','VO','VI','
     8VL','VM','VV','WE','WH','WI','WJ','WL','WP','WR','WY','XH','XJ','
     9XO','XQ','XU','XV','YC','YE','YH','YI','YL','YO','YR','YS','YU','
     1YX','ZA','ZD','ZE','EF','ZH','ZK','ZM','ZN','ZP','ZQ','ZR','ZS','
     2ZU','ZV','ZW','ZY','GS','YN'/
C  SCHEDULED HELICOPTER + OTHER
      DATA SHO    /'AD','CH','NY','OH','QW','CC','CF','DQ','DU','FT','
     1GZ','HJ','HX','JT','KT','MB','MQ','NX','OE','RI','RP','SB','VO','
     2ZO','FM','BB'/
C  AIRCRAFT 3 LETTER TYPE CODE FROM OAG, AC3LC(I),I=1,100
      DATA AC3LC/'ACD','A24','A50','BBR','BNI','BNT','BTP','B18','B88',
     1'399','CES','CVR','CV2','CV4','CV5','CV6','C46','DC3','DC6','DDV',
     2'DHC','DTO','FH7','F27','GGM','GGS','HRN','LEC','HR4','MU2','N26',
     3'PAZ','PCB','PCH','PDS','PHP','PNV','PPS','PRP','PR4','SKV','S72',
     4'SWM','S55','S61','TBB','TS4','Y11','Y14','Y18','482','47J','6B1',
     5'748','DHO','M28','TRK','  ','  ','A38','B11','B3J','DCA','DC9',
     6'J18','D8S','D9S','D95','F82','L18','S11','V18','707','72S','72B',
     7'727','73S','737','74L','747','888','998','Y62','YB6','JT','  ',
     8'  ','  ','  ','  ','  ',
     9'  ','  ','  ','  '/
C  AIRCRAFT SIZE, ENGINE AND BODY CODE, ACSEB(I),I=1,100
      DATA ACSEB/'S2T','L2T','S2P','S2P','S2P','S3P','S2T','S2P','S2T',
     1'S2T','S1P','L2T','L2P','L2P','L2T','L2T','L2P','L2P','L4P','S2P',
     2'L2P','S2T','L2T','L2T','S1P','S2P','L4T','L4T','L2T','S2T','L2T',
     3'S2P','S2T','S1P','L4P','L2T','S2P','S2P','L2P','S2P','S2T','L2T',
     4'S2T','O1H','O1H','S2P','S2T','L2T','L4P','L4T','S2T','O1H','S2P',
     5'L2T','S1P','S1P','S1P','  ','  ','H2W','L2S','H4S','H4S','L2S',
     6'H3H','H4S','L2S','L2S','L2S','H3W','L2S','L4S','H4S','L3S','L4S',
     7'L3S','L2S','L2S','H4W','H4W','L4S','L4S','H4S','H4W','L2S','  ',
     8'  ','  ','  ','  ',
     9'  ','  ','  ','  '/
      DATA BOARD/96,96,97,98,96,93,92,91,97,98,98,94,82,96,92,93,
     1102,91,95,89,97,86,95,92,87,87,83,90,89,85,82,90/
      DATA BOARDD/80/
```

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      DATA (LOAD(22,J),J=1,100)/61*0,40,55,0,80,46,52,0,4,44,3*0,51,0,49
     1,3*0,93,20*0/
      DATA (LOAD(23,J),J=1,100)/14*0,19,7*0,9,38*0,47,0,30,57,0,42,6*0,5
     14,56,43,0,46,0,83,20*0/
      DATA (LOAD(24,J),J=1,100)/23*0,10,37*0,30,62,27,55,52,34,6*0,43,64
     1,45,0,30,0,90,20*0/
      DATA (LOAD(29,J),J=1,100)/15*0,17,46*0,100,41,75,76,50,0,0,68,0,0,
     139,50,45,57,3*0,146,20*0/
      DATA (LOAD(32,J),J=1,100)/14*0,23,16,45*0,66,74,42,89,93,45,0,0,95
     1,3,0,62,57,0,59,41,3*0,72,19*0/
C LOAD0 IS AVERAGE SEATING CAPACITY
      DATA LOAD0/10,44,7,4,10,17,9,10,15,15,5,50,42,54,52,40,65,32,96,12
     1,31,19,44,48,7,12,16,87,40,9,21,5,7,6,16,19,7,6,32,12,19,23,19,15,
     233,10,6,68,85,100,6,2,5,58,9,3,1,00,00,251,74,144,146,77,242,
     3172,93,139,69,243,74,135,122,126,121,97,103,90,305,348,90,100,186,
     4234,8,15*0/
C HFACT0(I,J) IS PAX/DEPARTING SEAT AT APT I, HOUR J, NORMALIZED TO SUM C OVER J,
      DATA (HFACT(1,J),J=1,24)/44,36,39,10,12,12,85,99,104,107,141,165,
     1143,155,143,138,145,141,155,131,121,114,104,49/
      DATA (HFACT(2,J),J=1,24)/75,27,12,12,12,24,80,44,61,116,143,123,16
     10,171,148,177,162,111,152,121,179,100,107,75/
      DATA (HFACT(3,J),J=1,24)/68,13,50,55,13,65,80,100,95,150,100,175,
     1153,175,140,170,140,115,143,100,100,75,70,45/
      DATA (HFACT(4,J),J=1,24)/67,11,11,11,11,11,11,3,2,110,131,120,137,163
     1,153,142,150,148,148,174,155,142,137,95,142,11/
      DATA (HFACT(5,J),J=1,24)/148,127,13,45,13,47,59,55,95,111,113,142,
     1137,108,105,119,113,95,127,87,98,50,200,100/
      DATA (HFACT(6,J),J=1,24)/119,89,38,76,14,14,57,68,116,113,127,122,
     1151,132,122,146,143,127,100,81,100,70,167,95/
      DATA (HFACT(7,J),J=1,24)/16,16,62,16,50,16,5,105,110,127,145,139,1
     183,170,176,145,150,145,142,142,149,56,59,65/
      DATA (HFACT(8,J),J=1,24)/75,13,67,64,13,13,13,154,100,126,116,152,
     1167,147,134,136,162,157,129,134,111,93,82,36/
      DATA (HFACT(9,J),J=1,24)/12,12,21,12,12,13,81,113,116,123,110,134,
     1176,146,183,157,141,171,132,136,136,86,46,125/
      DATA (HFACT(10,J),J=1,24)/48,41,38,16,16,1,20,92,96,159,213,181,15
     10,140,115,140,194,159,180,172,16,86,96,24/
      DATA (HFACT(12,J),J=1,24)/12,12,12,12,12,12,28,100,149,139,137,179
     1,149,179,160,132,153,153,144,132,142,139,102,12/
      DATA (HFACT(13,J),J=1,24)/15,15,15,15,15,15,15,68,132,117,132,182,
     1159,180,153,156,162,198,132,159,141,99,66/
      DATA (HFACT(14,J),J=1,24)/12,24,12,12,12,2,68,92,120,126,138,193,1
     179,167,150,152,148,177,140,114,109,150,92,12/
      DATA (HFACT(15,J),J=1,24)/14,14,14,14,14,14,14,121,108,174,113,138
     1,157,166,146,138,171,182,171,149,121,91,127,30/
      DATA (HFACT(16,J),J=1,24)/13,13,26,60,13,34,29,105,123,182,134,184
     1,184,147,134,152,160,142,158,137,134,89,79,47/
      DATA (HFACT(17,J),J=1,24)/39,16,16,61,16,12,48,90,116,139,219,171,
     1160,136,139,187,155,158,136,103,94,74,90,16/
      DATA (HFACT(20,J),J=1,24)/16,39,10,14,14,6,73,81,140,151,163,160,
     1195,151,135,126,177,171,149,123,112,87,53,84/
      DATA (HFACT(22,J),J=1,24)/31,51,8,16,88,16,79,104,117,183,196,100,
     1114,120,117,114,136,152,129,152,73,63,85,79/
      DATA (HFACT(23,J),J=1,24)/103,18,18,18,18,31,53,92,113,128,103,124
     1,223,117,117,163,159,191,163,150,164,18,103,18/
      DATA (HFACT(24,J),J=1,24)/124,110,17,17,17,52,79,124,110,99,176,
     1159,166,120,124,152,173,117,176,93,62,45,16,104/
      DATA (HFACT(29,J),J=1,24)/68,15,46,15,15,15,101,95,132,114,126,200
     1,154,135,157,160,138,166,170,117,104,86,15,49/
      DATA (HFACT(32,J),J=1,24)/42,22,99,34,166,13,83,62,101,99,81,130,1
     156,148,146,140,127,133,138,114,114,143,96,13/
```

```
      WRITE(6,60000)PCOST
      WRITE(6,60000)TCOST
      WRITE(6,60000)LCOST
60000 FORMAT(13I6)
      DO 1 I=1,32
    1 WRITE(6,60001)(LOAD(I,J),J=1,100)
      WRITE(6,60001)LOAD0
60001 FORMAT(26I3)
      DO 2 I=1,32
    2 WRITE(6,60001)(HFACT(I,J),J=1,24)
      WRITE(6,60001)HFACT0
      WRITE(6,60001)BOARD
      WRITE(6,60001)BOARD0
      WRITE(6,60002)STK
      WRITE(6,60002)SLS
      WRITE(6,60002)SIS
      WRITE(6,60002)SIF
      WRITE(6,60002)SCT
      WRITE(6,60002)SHO
60002 FORMAT(26(1X,A2))
      WRITE(6,60003)ACSLC
      WRITE(6,60003)ACSEB
60003 FORMAT(20(1X,A3))
      END
```

APPENDIX B-4.   SIMULATOR, ANFS.F4

```
C   AIRPORT NETWORK FLOW SIMULATOR, VERSION  8
C   THE FOLLOWING FOUR CARDS ARE REQUIRED FOR RUNNING ON THE 10,
        OPEN(UNIT=5,DEVICE='DSK',ACCESS='SEQIN',FILE='FLIGHT.DAT')
        OPEN(UNIT=6,DEVICE='DSK',ACCESS='SEQOUT',FILE='ANFS.OUT')

        OPEN(UNIT=7,DEVICE='DSK',ACCESS='SEQIN',FILE='CAPCTY.DAT')
        OPEN(UNIT=9,DEVICE='DSK',ACCESS='SEQIN',FILE='COST.DAT')
C   THE ABOVE FOUR CARDS SHOULD BE REMOVED WHEN RUNNING ON THE 360,
C   NOTES: ALL TIMES IN SECONDS GMT, UNLESS OTHERWISE NOTED
C           TAU INCLUDES NORMAL SERVICE TIME
C           TAU MUST BE NDLEG FOR THE LAST EVENT OF EACH AIRCRAFT
C           SIG IS MINIMUM INTERVAL BETWEEN INTIATIONS OF SERVICE
C   TS,TAU,TA,LM,IJ,CECODE ARE DIMENSIONED TO NO OF EVENTS, NEVNTS
C   TAX,TAY,MX,MY ARE DIMENSIONED TO MAX NO OF EVENTS AT ANY AIRPORT
C   TAO,APT,ZONE ARE DIMENSIONED TO  NO OF AIRPORTS, NAPTS
C   ML IS DIMENSIONED TO  NO OF AIRPORTS PLUS ONE
C   ALL OTHER DIMENSIONS ARE INDEPENDENT OF NEVNTS AND NAPTS
        INTEGER*2 CECODE(8000),MY(2000),ML(240),LM(8000),IJ(8000),MX(2000)
        INTEGER LCOST(100),TCOST(100), LOAD(32,100),SIGO(24),ZONE(240)
        INTEGER  LOAD0(100),HFACT0(24),HFACT(32,24),COST(4,25),COSTS(4,25)
        INTEGER TAO(240),C(4),APT(240),SIGX(24),SIG(32,25),D(4),OUTP(4,25)
        INTEGER OUTS(4,25),TS(8000),TAU(8000),TA(8000),TAX(2000),TAY(2000)
        INTEGER PCOST,OUT,PLEVEL,SKED,NSKD,TOTL,BOARD(32),BOARDO
        INTEGER GFACX(24),E(4),EQSEB(100),EQ3LC(100),GAFAC(32,25),VOL(24)
        INTEGER T1,T2,TA1,TAMIN,HOUR,ST,TY,TX,TZ,ALL,TSTART,TSTOP,EXPFAC
        INTEGER APTS32(32),XFORM(32),NSVOL(24),NTOTL(24),SIGON(24)
        DATA APTS32  /'ORD ','ATL ','JFK ','LGA ','SFO ','LAX ','DEN ',
       1'PHL ','EWR ','MIA ','DAL ','DCA ','PIT ','BOS ','CLE ','DTW ',
       2'MSY ','LAS ','HNL ','STL ','FLL ','TPA ','MSP ','SEA ','BAL ',
       3'CLT ','MKE ','SLC ','IAH ','IAD ','JAX ','DFW '/
        DATA ALL,OUT,E/'ALL ','OUT','TKOF','LNDG','ADLY','BDLY'/
        DATA SKED,NSKD,TOTL/'SKED','NSKD','TOTL'/
        WRITE(6,6666)
 6666 FORMAT(' THE AIRPORT NETWORK FLOW SIMULATOR'/////)
C
C   READ SCHEDULED DEMAND DATA FROM ANFS.DAT
        READ(5,5001)NAPTS
 5001 FORMAT(I10)
        READ(5,5002)(APT(K),K=1,NAPTS)
 5002 FORMAT(20A4)
        READ(5,5003)(ZONE(K),K=1,NAPTS)
 5003 FORMAT(20I4)
        READ(5,5004)NACFT,NEVNTS
 5004 FORMAT(2I10)
        READ(5,5005)((LM(K),TS(K),TAU(K),CECODE(K)),K=1,NEVNTS)
 5005 FORMAT(I3,3I6)
C
C   READ CAPACITY DATA FROM CAPATY.DAT
C   EXPFAC IS TRAFFIC EXPANSION FACTOR IN PERCENT BASED ON 100 FOR
C   UNEXPANDED TRAFFIC LEVEL  (SAME FOR CARRIER AND GA)
C   PLEVEL IS AIRPORT PRINT LEVEL IN ACFT-MINS OF TOTAL DELAY
C   MAXGI IS MAXIMUM GROUND TIME IN MINUTES
C   KSLACK IS REDUCTION IN GROUND SLACK TIME, IN MINUTES
C   KAPT IS AIRPORT 3-LETTER CODE
C   SIGX IS RUNWAY SERVICE TIME IN SEC (SAME FOR CARRIER AND GA)
C   KGA IS DAILY GA OPS AS PERCENT OF TOTAL DAILY OPS
C   GFACX IS GA PROFILE BY HOUR (EACH HOUR'S PERCENT OF DAILY GA OPS)
C   LAST KAPT ENTERED MUST BE ALL
C   IF KAPT IS ALL KGA APPLIES TO ALL REMAINING AIRPORTS AND GFACX
C   IS HOURLY PROFILE FOR SCHED AND NONSCHED AT REMAINING AIRPORTS
        READ(7,7010)EXPFAC,PLEVEL,MAXGT,KSLACK
```

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```
7010 FORMAT(I8,10I6)
     IAPT1 = 0
     NAPTSG = 0
   1 READ(7,7011)KAPT,SIGX
7011 FORMAT(1X,A4,24I3)
     READ(7,7012)KGA,GFACX
7012 FORMAT(1X,I4,24I3)
     IF(KAPT.EQ.ALL)GO TO 2
     DO 1003 K=1,NAPTS
     IF(KAPT.EQ.APT(K))GO TO 1005
1003 CONTINUE
     WRITE(6,6008)KAPT
6008 FORMAT(/1X,'INPUT AIRPORT ',A4,'NOT IN DATA BASE')
     GO TO 1
1005 NAPTSG = NAPTSG + 1
     IF(NAPTSG.GT.32)GO TO 1
     SIG(NAPTSG,25) = K
     GAFAC(NAPTSG,25) = KGA
     DO 1008 K=1,24
     GAFAC(NAPTSG,K) = GFACX(K)
1008 SIG(NAPTSG,K) = (SIGX(K)*EXPFAC)/100
     GO TO 1
   2 DO 3 J=1,24
     IF(SIGX(J).GT.0)IAPT1 = ALL
     IF(KGA.EQ.100)KGA = 95
     SIGON(J) = SIGX(J)*EXPFAC
   3 SIGO(J) = (SIGX(J)*EXPFAC)/(100-KGA)
C
C  READ COST DATA FROM COST.DAT
C  PCOST, TCOST, LCOST ARE CENTS/HR FOR PAX, TAKEOFF, LANDING
C  LOAD(I,J) IS AVG PAX LOAD (LNDG OR TAKNG OFF) ON ACFT TYPEJ, APT I.
C  LOADO IS SEATING CAPACITY OF AIRCRAFT TYPE J
C  HFACT(I,J) IS PAX LOAD IN HR J AS PERCENT OF AVG HOURLY LOAD, APT I
C  (SAME FOR ALL AIRCRAFT TYPES).  HFACTO(J) IS HFACT(I,J) FOR I GT 32.
C  XFORM(J),J=1,32 HOLDS APT NUMBERS L FOR THE 32 APTS OF THE ARRAYS
C  LOAD, LOADO, HFACT, HFACTO .
C  SIG(J,1-24) HOLDS SERVICE TIMES FOR J=1,NAPTSG
C  SIG(J,25) HOLDS APT NUMBER L CORRESPONDING TO J.
     READ(9,9000)PCOST
     READ(9,9000)TCOST
     READ(9,9000)LCOST
9000 FORMAT(13I6)
     DO 4 I=1,32
   4 READ(9,9001)(LOAD(I,J),J=1,100)
9001 FORMAT(26I3)
     READ(9,9001)LOADO
     DO 5 I=1,32
   5 READ(9,9001)(HFACT(I,J),J=1,24)
     READ(9,9001)HFACTO
     READ(9,9001)BOARD
     READ(9,9001)BOARDO
C    READ(9,9002)STK
C    READ(9,9002)SLS
C    READ(9,9002)SIS
C    READ(9,9002)SIF
C    READ(9,9002)SCT
C    READ(9,9002)SHO
C9002 FORMAT(26(1X,A2))
C    READ(9,9003)AC3LC
C    READ(9,9003)ACSEB
C9003 FORMAT(20(1X,A3))
```

```
C
C   INITIALIZE
      INTVL = 600
      TSTART = 36000
      TSTOP = TSTART + 97200
      LOUT = 0
      NAPTS1 = NAPTS + 1
      MSLACK = 0
      NSLACK = 0
      NDLEG = 43201
      NAPTSX = NAPTS - 1
      IF(PLEVEL.EQ.0)PLEVEL=15
      MAXGT0 = MAXGT
      KSLAK0 = KSLACK
      KPLVL0 = PLEVEL
      PLEVEL = PLEVEL*60
      MAXGT = MAXGT*60
      KSLACK = KSLACK*60
      MAXGT = MAXGT + KSLACK
      DO 6 L=1,NAPTS
      IF(APT(L).EQ.OUT)LOUT = L
      TA0(L) = 0
      ML(L) = 0
      DO 6 I=1,32
    6 IF(APT(L).EQ.APTS32(I))XFORM(I)=L
      DO 7 K=1,4
      DO 7 J=1,25
      COSTS(K,J) = 0
    7 OUTS(K,J) = 0
C   FILL IN TA(K), LM(K), IJ(K), ML(L), ADJUST SCHEDULE FOR INTVL
      DO 8 K=2,NEVNTS,2
      K1 = K-1
      IF(TAU(K1).LT.INTVL)TAU(K1)=INTVL
      TS(K) = TS(K1) + TAU(K1)
      L = LM(K1)
      ML(L) = ML(L) + 1
      L = LM(K)
      ML(L) = ML(L)+1
      IF(TAU(K).EQ.NDLEG)GO TO 8
      KTAU = TAU(K) + KSLACK
      MTAU =TS(K+1) -TS(K)
      TAU(K) = MINO(MTAU,MAXGT,KTAU)
      IF(TAU(K).LT.INTVL)TAU(K)=INTVL
      IF((TS(K+1)-TS(K)).LT.TAU(K))TS(K+1) = TS(K) + TAU(K)
      MSLACK = MSLACK + TS(K+1) - TS(K) - TAU(K)
      NSLACK = NSLACK + 1
    8 CONTINUE
      XSLACK = FLOAT(MSLACK)/FLOAT(NSLACK)/60.
      MSAVE = ML(1)
      ML(1) = 1
      DO 9 L = 2,NAPTS1
      MHOLD = ML(L)
      ML(L) = ML(L-1) + MSAVE
    9 MSAVE = MHOLD
      KLMMAX = ML(NAPTS1) - 1
      IF(KLMMAX.NE.NEVNTS)STOP 21
      DO 10 K=1,NEVNTS
      L = LM(K)
      K2 = ML(L)
      ML(L) = K2 + 1
      LM(K) = K2
```

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```
          TA(K2)  = TS(K)
      10  IJ(K2)  = K
C  SET ML(L) TO STARTING LOCATION IN TA ARRAY FOR AIRPORT L
          DO 11 L=1,NAPTSX
          L2=NAPTS1-L
      11  ML(L2) = ML(L2-1)
          ML(1) = 1
C  FILL IN LOAD(I,J) AND HFACT(I,J)
C  CHANGE LOAD0 TO BE PAX LOAD AT 50% LOAD FACTOR
          DO 12 J=1,100
          LOAD0(J) = LOAD0(J)/2
          DO 12 I=1,32
          IF(J.GT.24)GO TO 12
          IF(HFACT(I,J).EQ.0)HFACT(I,J) = HFACT0(J)
      12  IF(LOAD(I,J).EQ.0)LOAD(I,J) = LOAD0(J)
C  CALCULATE NEW SIG FROM VOL AND GAFAC
          IF(NAPTSG.EQ.0)GO TO 99
C  PRINT OUT VOLUMES BY APT AND HOUR
          WRITE(6,6667)(I,I=1,23)
    6667  FORMAT(//' LCL HR   0'11I4/6X,12I4,7X'TOT'//)
          DO 25 J=1,NAPTSG
          L = SIG(J,25)
          K2 = ML(L+1) - 1
          K1 = ML(L)
          NOPS = K2 -K1 + 1
          DO 20 I=1,24
      20  VOL(I) = 0
          DO 22 M=K1,K2
          TY = TA(M)
          I = ((TY/3600) - ZONE(L) + 24)
          LOCLHR = MOD(I,24) + 1
      22  VOL(LOCLHR) = VOL(LOCLHR) + 1
          KGA = GAFAC(J,25)
          KTEMP = 100*(100-KGA)
          MTEMP = KGA*NOPS
          NSTOT = 0
          DO 24 I=1,24
          JTEMP = VOL(I)*KTEMP
          JTEMP = MAX0(JTEMP,1)
          NSVOL(I) = (GAFAC(J,I)*MTEMP)/KTEMP
          NSTOT = NSTOT + NSVOL(I)
          NTOTL(I) = NSVOL(I) + VOL(I)
          SIGX(I) = SIG(J,I)
          LTEMP = (SIG(J,I)*(JTEMP+GAFAC(J,I)*MTEMP))/JTEMP
      24  SIG(J,I) = MIN0(LTEMP,1800)
          WRITE(6,6000)L,APT(L)
          WRITE(6,6668)
    6668  FORMAT(/' HOURLY DEMAND (AIRCRAFT)')
          WRITE(6,6001)SKED,(VOL(I),I=1,24),NOPS
          WRITE(6,6001)NSKD,(NSVOL(I),I=1,24),NSTOT
          NOPTOT = NOPS + NSTOT
          WRITE(6,6001)TOTL,(NTOTL(I),I=1,24),NOPTOT
          WRITE(6,6669)
    6669  FORMAT(/' SERVICE TIME (SECONDS)')
          WRITE(6,6001)SKED,(SIG(J,I),I=1,24)
          WRITE(6,6001)TOTL,(SIGX(I),I=1,24)
      25  CONTINUE
          WRITE(6,6000)LOUT,ALL
          WRITE(6,6669)
          WRITE(6,6001)SKED,(SIG0(I),I=1,24)
          WRITE(6,6001)TOTL,(SIGN(I),I=1,24)
```

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```
      WRITE(6,6025)XSLACK
 6025 FORMAT(/// MEAN GROUND SLACK TIME (MINUTES)    ',F5.1/)
      WRITE(6,6026)EXPFAC,KPLVLO,MAXGTO,KSLAKO
 6026 FORMAT(' EXPFAC = ',T5,4X,'PLEVEL = ',I3,4X,'MAXGT = ',I3,
     14X,'KSLACK = ',I2//)
C
C SET TIME INTERVAL (T1,T2), AND EXAMINE EACH AIRPORT
   99 T2 = TSTART
  100 T1 = T2
      T2 = T1 + INTVL
      DO 200 L=1,NAPTS
      IF(L.EQ.LOUT)GO TO 200
      ISAVE = 0
      DO 103 I=1,NAPTSG
  103 IF(SIG(I,25).EQ.L)ISAVE = I
C SKIP AIRPORT IF ZERO OR NO SERVICE TIME HAS BEEN INPUT
      IF(ISAVE.EQ.0.AND.IAPT1.NE.ALL)GO TO 200
  105 K1 = ML(L)
      K2 = ML(L+1)=1
      K = 0
C SELECT M FOR TA GE T1 AND LT T2    PUT TA INTO TAX ARRAY, M INTO MX.
      DO110 M=K1,K2
      TA1 = TA(M)
      IF(TA1.LT.T1.OR.TA1.GE.T2) GO TO 110
      K=K+1
      MX(K) = M
      TAX(K) = TA1
  110 CONTINUE
      IF(K.EQ.0)GO TO 200
      KMAX = K
C PUT TAX INTO TAY ARRAY IN TIME ORDER
      DO 125 KY=1,KMAX
      TAMIN = 1000000
      DO 120 K=1,KMAX
      IF(TAX(K).GE.TAMIN)GO TO 120
      TAMIN = TAX(K)
      KMIN = K
  120 CONTINUE
      MY(KY) = MX(KMIN)
      TAY(KY) = TAMIN
  125 TAX(KMIN) = 1000000
      TY = TAO(L)
C SELECT SERVICE INTERVAL, SIGX
      IF(ISAVE.GT.0)GO TO 135
      DO 132 J=1,24
  132 SIGX(J) = SIG0(J)
      GO TO 150
  135 DO 137 J=1,24
  137 SIGX(J) = SIG(ISAVE,J)
C ADVANCE TAY BY MINIMUM SERVICE INTERVAL, RESET TA
  150 DO 160 K=1,KMAX
      LOCLHR = ((TY/3600) = ZONE(L) + 24)
      LOCLHR = MOD(LOCLHR,24) + 1
      ST = SIGX(LOCLHR)
      TY = TY + ST
      IF(TY.LT.TAY(K))TY=TAY(K)
      M=MY(K)
      TA(M) = =TY
      TX = TY
      KIJ = IJ(M) = 1
  155 KIJ = KIJ + 1
```

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```
          KTAU = TAU(KIJ)
          IF(KTAU.EQ.NDLEG)GO TO 160
          TX = TX + KTAU
          M1 = LM(KIJ+1)
          IF(TX.LE.TA(M1))GO TO 160
          TA(M1) = TX
          GO TO 155
     160 CONTINUE
          TAO(L) = TY
C         WRITE(6,5000)(TA(M),M=K1,K2)
C5000 FORMAT(10I8)
     200 CONTINUE
C
C   STOP AT 27 HOURS AFTER TSTART
          IF(T2.LT.TSTOP)GO TO 100
C
C   OUTPUT FROM TSTART TO TSTART + 24 HOURS
C
          I1 = TSTART/3600
          I136 = I1*3600
          I2 = I1 + 23
          IX = I1 + 1
          WRITE(6,6060)I1,(I,I=IX,I2)
    6060 FORMAT(//////' HOURLY DELAY (AIRCRAFT-MINUTES)'//1X,'GMT HR'I3,
         1 11I14/6X,12I4,7X,'TOT'4X,'DOLS'//)
          DO 600 L=1,NAPTS
          DO 400 K=1,25
          DO 400 J=1,4
          COST(J,K) = 0
     400 OUTP(J,K) = 0
          KFLAG = 0
          DO 410 I=1,32
     410 IF(XFORM(I).EQ.L)KFLAG=I
C   CALCULATE DELAYS FOR AIRPORT L
          ML1= ML(L)
          ML2 = ML(L+1) - 1
          DO 500 M=ML1,ML2
          J = IJ(M)
          TX = TA(J)
          HOUR = ((TX-I136)/3600) + 1
          IF(HOUR.LT.1)GO TO 500
          IF(HOUR.GT.24)GO TO 500
          J1=J-1
          KTYPE = CECODE(J)
          KTYPE = MOD(KTYPE,100)
          LOCLHR = ((TX/3600)  -ZONE(L)+24)
          LOCLHR = MOD(LOCLHR,24) + 1
          IF(KFLAG.GT.0)NPAX=(LOAD(KFLAG,KTYPE)*HFACT(KFLAG,LOCLHR))/100
          IF(KFLAG.EQ.0)NPAX=(LOAD0(KTYPE)*HFACT0(LOCLHR))/100
          MTA = TA(M)
          ABSMTA = ABS(MTA)
          IF(MOD(J,2).EQ.0)GO TO 490
C  J ODD, OPERATION IS A DEPARTURE
          IF(J1.GT.0.AND.TAU(J1).NE.NDLEG)GO TO 480
          TY = TX
          GO TO 485
     480 M1 = LM(J1)
          M1TA = TA(M1)
          TY = ABS(M1TA) + TAU(J1)
     485 MAXYTO = MAXO(TX,TY)
          D(1)= ((ABSMTA - MAXYTO)*EXPFAC)/100
```

```
      D(4)= ((MAXYTO - TX)*EXPFAC)/100
      C(1) =(D(1)*(TCOST(KTYPE) + PCOST*NPAX))/3600
      C(4) =(D(4)*PCOST*NPAX)/3600
      IF(KFLAG.EQ.0)C(4)=(C(4)*BOARD0)/100
      IF(KFLAG.GT.0)C(4)=(C(4)*BOARD(KFLAG))/100
      OUTP(1,HOUR) = OUTP(1,HOUR) + D(1)
      OUTP(4,HOUR) = OUTP(4,HOUR) + D(4)
      COST(1,HOUR) = COST(1,HOUR) + C(1)
      COST(4,HOUR) = COST(4,HOUR) + C(4)
      GO TO 500
C  J EVEN, OPERATION IS AN ARRIVAL
  490 M1 = LM(J1)
      M1TA = TA(M1)
      TY = ARS(M1TA) + TAU(J1)
      D(2) = ((ARSMTA - TY)*EXPFAC)/100
      C(2) = (D(2)*(LCOST(KTYPE) + PCOST*NPAX))/3600
      OUTP(2,HOUR) = OUTP(2,HOUR) + D(2)
      COST(2,HOUR) = COST(2,HOUR) + C(2)
  500 CONTINUE
C SUM OVER 24 HOURS
      DO 501 K=1,4
      C(K) = 0
  501 D(K) = 0
      DO 503 HOUR=1,24
      OUTP(3,HOUR) = OUTP(1,HOUR) + OUTP(2,HOUR)
      COST(3,HOUR) = COST(1,HOUR) + COST(2,HOUR)
      DO 503 K=1,4
      D(K) = D(K) + OUTP(K,HOUR)
      C(K) = C(K) + COST(K,HOUR)
      COSTS(K,HOUR) = COSTS(K,HOUR) + COST(K,HOUR)
  503 OUTS(K,HOUR) = OUTS(K,HOUR) + OUTP(K,HOUR)
      DO 510 K=1,4
      OUTP(K,25) = D(K)
      COST(K,25) = C(K)
      OUTS(K,25) = OUTS(K,25) + D(K)
  510 COSTS(K,25) = COSTS(K,25) + C(K)
      IF((OUTP(3,25)+OUTP(4,25)).LT.PLEVEL)GO TO 600
C  CONVERT OUTP DELAYS TO MINUTES AND COST TO DOLLARS AND PRINT OUT
      DO 520 K=1,25
      DO 520 J=1,4
      OUTP(J,K) = OUTP(J,K)/60
  520 COST(J,K) = COST(J,K)/100
      WRITE(6,6000)L,APT(L)
 6000 FORMAT(/1X,I4,1X,A4)
      DO 528 K=1,4
  528 WRITE(6,6001)(E(K),(OUTP(K,J),J=1,25),COST(K,25))
  600 CONTINUE
C
C  CONVERT OUTS DELAYS TO HOURS AND COSTS TO $K AND PRINT OUT
      DO 720 J=1,4
      DO 720 K=1,25
      OUTS(J,K) = (OUTS(J,K)+1800)/3600
  720 COSTS(J,K) = (COSTS(J,K)+50000)/100000
      WRITE(6,6005)
 6005 FORMAT(//1X,'TOTAL DELAY IN HOURS')
      DO 728 K=1,4
  728 WRITE(6,6001)(E(K),(OUTS(K,J),J=1,25))
 6001 FORMAT(1X,A4,1X,12I4/6X,12I4,I10,I8)
      WRITE(6,6006)
 6006 FORMAT(//1X,'TOTAL COST IN THOUSANDS OF DOLLARS')
      DO 738 K=1,4
```

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```
738 WRITE(6,6001)(E(K),(COSTS(K,J),J=1,25))
    STOP
    END
```

APPENDIX B-5.   ANFS OUTPUT, ANFS.OUT

THE AIRPORT NETWORK FLOW SIMULATOR

LCL HR	0	1	2	3	4	5	6	7	8	9	10	11		TOT
	12	13	14	15	16	17	18	19	20	21	22	23		

1 JFK

HOURLY DEMAND (AIRCRAFT)

SKED	14	9	11	1	1	3	19	20	29	37	35	25		732
	30	30	40	45	61	64	54	64	41	55	25	19		
NSKD	1	0	1	1	0	0	1	1	2	3	2	1		50
	2	1	2	4	4	5	5	4	3	4	2	1		
TOTL	15	9	12	2	1	3	20	21	31	40	37	26		782
	32	31	42	49	65	69	59	68	44	59	27	20		

SERVICE TIME (SECONDS)

SKED	68	64	66	136	98	72	64	65	65	65	64	64
	65	63	63	65	64	64	65	64	65	64	66	66
TOTL	60	60	60	60	60	60	60	60	60	60	60	60
	60	60	60	60	60	60	60	60	60	60	60	60

133 ALL

SERVICE TIME (SECONDS)

SKED	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
TOTL	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0

MEAN GROUND SLACK TIME (MINUTES)   52.6

EXPFAC =   100   PLEVEL = 600   MAXGT = 60   KSLACK = 9

HOURLY DELAY (AIRCRAFT-MINUTES)

GMT HR	10	11	12	13	14	15	16	17	18	19	20	21		TOT	DOLS
	22	23	24	25	26	27	28	29	30	31	32	33			

1 JFK

TKOF	0	0	5	15	91	61	23	53	15	20	29	167		3266	80516
	599	715	716	417	312	18	2	1	0	0	0	0			
LNDG	0	7	5	13	12	16	12	13	39	59	99	514		3112	84912
	527	543	662	374	180	12	2	9	1	1	0	0			
ADLY	0	8	11	29	104	70	36	67	54	80	128	682		6378	165429
	1127	1258	1378	792	492	31	4	10	1	1	0	0			

BDLY	0	0	0	5	3	0	0	4	2	10	14	8		
	62	143	128	48	40	15	0	0	0	0	0	0	488	6193
2 BDR														
TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	1	0	0	0	9	0	0	0	0		
	13	0	24	0	0	0	0	0	0	0	0	0	49	102
3 ORD														
TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	20	0	22	0	0	0	0	1	0		
	0	0	0	20	0	22	0	0	0	0	0	0	44	895
5 BDL														
TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	4	0	0	0	0	0	0		
	7	0	0	0	0	0	0	0	0	0	0	0	11	282
6 LGA														
TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	1	0	0	0	0	2	0	4	0		
	27	23	0	26	0	0	0	0	0	0	0	0	85	399
7 SFO														
TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	7		
	0	0	0	0	0	0	0	5	3	0	0	0	16	356
9 DEN														
TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	6	0	0		

0	0	0	0	15	0	0	0	0	0	0	0	0	22	566

10 PHL

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	5		
	11	0	0	0	0	33	0	0	0	0	0	0	50	622

13 DCA

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	15	20	0	18	0	0	0	0	0	0	53	869

14 PIT

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	3	0		
	2	1	19	0	19	0	0	0	0	0	0	0	46	630

16 CLE

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	18	21	0	0	0	0	0	0	0	0	40	675

17 DTW

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	30	0	0	0	0	0	0	0	1	32	577

18 MSY

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	21	12	0	0	7	0	0	0	42	301

19 LAS

TKOF	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	22	0	0		22	23₁

21 STL

TKOF	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	21	25	0	17	0	0	0	0		64	600

22 FLL

TKOF	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	17	30	0	0	54	0	0	0	0		104	863

23 TPA

TKOF	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	6	2		
	0	0	0	14	0	30	0	0	0	0	0	0		54	419

25 SEA

TKOF	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	24	0	0	0	0		24	110

26 BAL

TKOF	0	0	0	0	0	0	0	0	0	0	0	0			
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	3	0	0	5	0	0	0	2			
	1	0	25	0	0	0	0	0	0	0	0	0		38	436

28 MKE

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	23	0	0	0	0	0	0	23	461

30 IAH

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	9	0	0	10	16

31 IAD

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	5	13	0	0	0	9	0	0	0	0	0	0	28	429

32 JAX

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	2	0	0		
	0	0	5	0	14	0	0	0	0	0	0	0	21	175

33 DFW

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	15	0	0	0	0	0	0	0		
	0	0	0	0	15	0	15	0	0	0	0	0	31	359

34 HVN

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	4	0	0	0	0	0	1	0		
	0	0	24	0	0	0	0	0	0	0	0	0	30	56

47 ALB

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	8	0	0		
	0	22	0	0	29	0	0	0	0	0	0	0	60	475

52 BGM

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	1	0	0		
	0	0	0	41	0	0	0	0	0	0	0	0	42	31

60 POU

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	2	0	0	0	0	0		
	0	0	18	0	47	0	0	0	0	0	0	0	67	78

63 MCO

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	5	15	14	0	0	0	0	0	0	34	234

66 DAB

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	2	0		
	0	0	0	0	0	14	0	0	0	0	0	0	16	91

79 CHS

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	22	0	0	0	0	0	0	0	22	116

81 ORF

TKOF	0	0	0	0	0	0	0	0	0	0	0	0

	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	20	0	0	0	18	0	0	0	0	0	18	398

82 PHF

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	20	0	0	0	0	0	0	0	0	0	0	20	116

101 BNA

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	25	0	0	0	0	0	0	0	0	25	352

102 MEM

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	25	0	0	0	0	0	0	25	173

115 TUL

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	13	0	0	0	0	0	0	0	13	148

122 PHX

TKOF	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	12	0	0	0	21	0	0	34	279

129 YUL

TKOF	0	0	0	0	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LNDG	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ADLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	33	0	0	0	0	0	0	0	0	33	273

TOTAL DELAY IN HOURS

TKOF	0	0	0	0	2	1	0	1	0	0	0	3		
	10	12	12	7	5	0	0	0	0	0	0	0	54	
LNDG	0	0	0	0	0	0	0	0	1	1	2	9		
	9	9	11	6	3	0	0	0	0	0	0	0	52	
ADLY	0	0	0	0	2	1	1	1	1	1	2	11		
	19	21	23	13	8	1	0	0	0	0	0	0	106	
BDLY	0	0	0	0	0	0	0	0	0	0	1	1		
	2	4	5	5	5	4	1	2	0	1	0	0	33	

TOTAL COST IN THOUSANDS OF DOLLARS

TKOF	0	0	0	0	3	2	1	2	0	0	1	4		
	15	21	15	11	6	0	0	0	0	0	0	0	81	
LNDG	0	0	0	0	0	0	0	0	2	2	4	13		
	16	14	18	10	4	0	0	0	0	0	0	0	85	
ADLY	0	0	0	0	3	2	1	2	2	2	5	17		
	32	35	33	21	10	1	0	0	0	0	0	0	165	
BDLY	0	0	0	0	0	0	0	0	0	1	1	1		
	1	3	3	4	3	3	0	1	0	0	0	0	21	

APPENDIX C: USER'S GUIDE TO ANSF

This Appendix provides information on running the Airport Network Flow Simulator (ANFS) and its associated programs. Although the programs have been constructed and tested on the DEC-10 computer system at TSC, they have been written in ASA Level G FORTRAN IV, and employ few machine-dependent features. Hence they should be transferrable to other computers without extensive revision of the FORTRAN statements. For the sake of clarity, however, the file designation convention employed in this description is that of the DEC-10 system: a program or data file is identified by a file name of up to six characters, followed by a period and a three-character file extension name.

The ANFS and its supporting programs and data files have been recorded on 9 and 7-track magnetic tapes. Together with the sample outputs in Appendix B of the present report, they constitute a complete test case for the airport JFK (John F. Kennedy, N.Y.).

The interrelation of the programs and data files is shown in Figure C-1. FORTRAN IV programs are distinquished by the file name extension .F4, and data files by the extension .DAT. The box labelled TTY represents the user's teletype, or, in the case of some batch job systems, a set of user-supplied punched cards. The arrows indicate the flow of data between FORTRAN programs and data files. Table C-1 provided detailed lists of the data and formats corresponding to the (   ) numbers on the flow lines, and Table C-2 provides definitions for the variables.

The data identified as (1), (2), (3), (4), (6), (7) and (8) described more fully in Section 2. of this report. The ANFS outputs (5) are described in Section 4. and Appendix B-5 of this report.

C-1

COST.F4

ANFS.OUT

CAPCTY.DAT

(7)

(5)

(8)

COST.DAT

(6)

ANFS.F4

ANFS.DAT

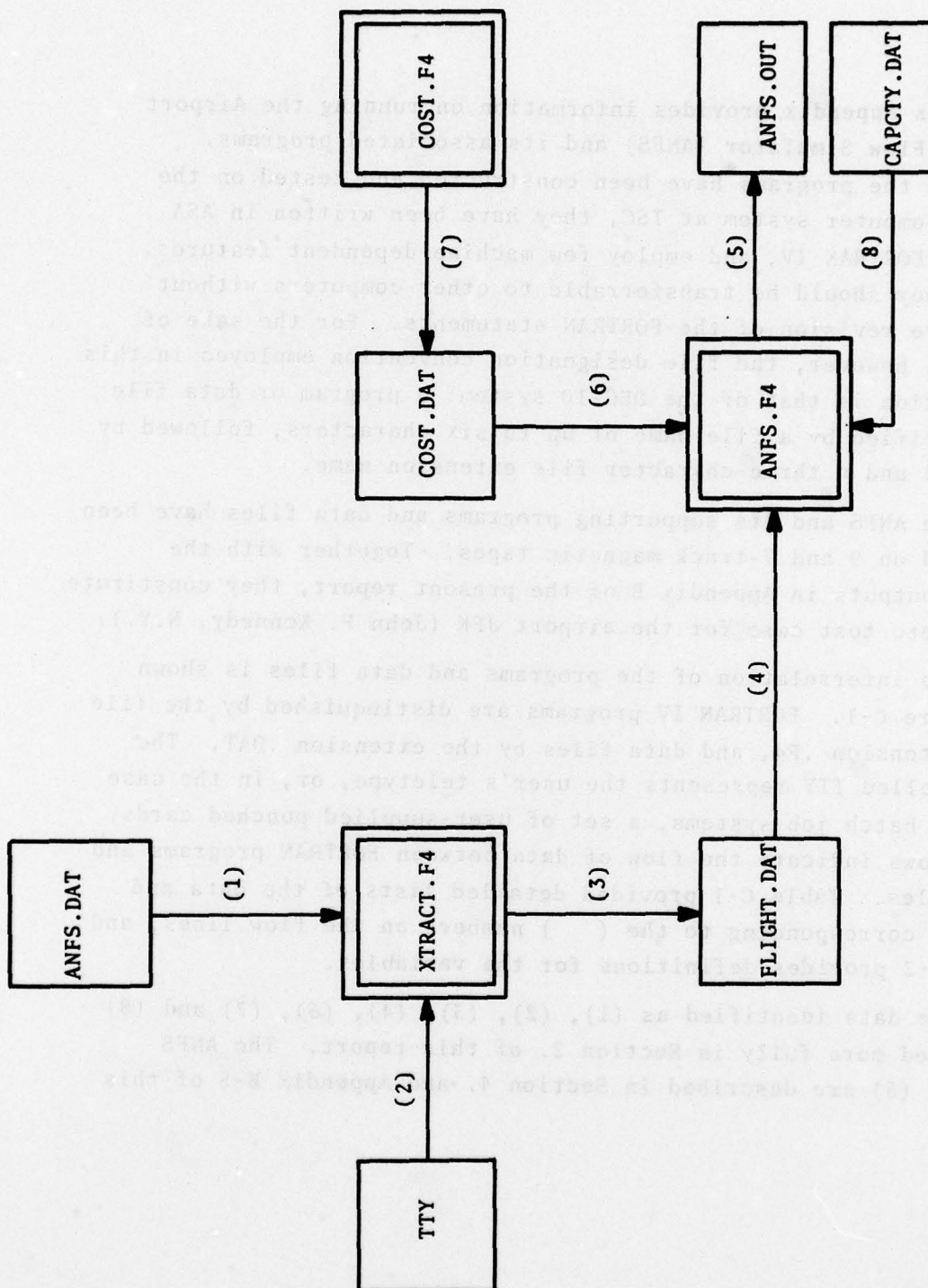(1)

XTRACT.F4

(3)

FLIGHT.DAT

(4)

(2)

TTY

FIGURE C-1. INTERRELATION OF FORTRAN PROGRAMS AND DATA FILES

TABLE C-1: DATA FLOW FOR FIGURE C-1

(1) NAPTS
    APT(I), I=1, NAPTS
    ZONE(I), I=1, NAPTS
    NACFT, NEVNTS
    (LM(K), TS(K), TAUCK), CODE(K)), K=1, NEVNTS

(2) IAPT

(3) Same as (1)

(4) Same as (1)

(5) See Appendix B-5

(6) PCOST
    TCOST(I), I=1,100
    LCOST(I), I=1,100
    (LOAD(I,J), J=1,100), I=1,32
    LOADφ(J), J=1,100
    (HFACT(I,J), J=1,24), I=1,32
    HFACTφ(J), J=1,24
    BOARD(I), I=1,32
    BOARDφ

(7) Same as (6)

(8) EXPFAC
    PLEVEL
    MAXGT
    KSLACK
    APT,(SIG(I), I=1,24)
    KGA,(GFAC(I), I=1,24)

C-3

TABLE C-2.   DEFINITIONS OF VARIABLES IN TABLE C-1

(1) NAPTS   = Number of airports in demand file, ANFS.DAT

     APT(I)   = Three-letter identifier for Ith airport in
                  ANFS.DAT file

     ZONE(I)   = Time zone for Ith airport in ANFS.DAT file,
                  equal to the number of hours difference in
                  time between the airport location and Green-
                  wich

     NACFT   = Number of aircraft in ANFS.DAT file

     LM(K)   = Airport number, I, at which Kth event takes
                  place

     TS(K)   Time at which Kth event is scheduled to take
                  place, seconds from GMT midnight.

     TAU(K)   = Minimum allowable time between event K and event
                  K+1, seconds

     CODE(K)   = Carrier-Equipment code for Kth event (See
                  Section 2.1.3)

(2) IAPT   = Three-letter identifier for airport for which
                  traffic is to be extracted from the demand
                  file ANFS.DAT

(3) The variables put into the extracted demand file FLIGHT.
     DAT are the same as the full demand file ANFS.DAT, except
     that (1) the number of airports NAPTS is fewer (2) the
     airport identifiers and zones are fewer and in a different
     order, the first one in the extracted list being IAPT,
     (3) the number of aircraft NACFT is usually fewer, (4)
     the number of events NEVNTS is fewer, (5) the event data
     LM(K), TS(K), TAU(K), CODE(K) are given only for aircraft
     in the extracted file, which aircraft may be arranged in
     an order different from their order in ANFS.DAT.

(4) Same as (3) above

(5) See Appendix B-5 and Section 4 of this report.

(6) PCOST   = The value of passenger time, ¢/hr

C-4

TCOST(I)   = Operating cost per hour of take-off delay,
              aircraft type I

LCOST(I)   = Operating cost per hour of landing delay,
              aircraft type I

LOAD(I,J)   = Number of passengers per departure at airport
              I, aircraft type J

LOAD∅   = Number of passengers per departure aboard
              aircraft type, airports other than those
              specified in LOAD(I,J)

HFACT(I,J) = Hourly load factor, passengers per departing
              seat at airport I, local hour J, normalized
              to average load factor for all hours at
              airport I.

BOARD(I)   = Percentage of continuing passengers, relative
              to departing passengers, for airport I.

BOARD∅   = Same as BOARD(I) for airports not covered
              by index I.

(7) Same as (6) above

(8) See Table 2.2 in text

ANFS.DAT   This is the master file of demand de-
                   scribed in Section 2.1.3 of this report.
                   It corresponds to the Official Airline
                   Guide flights for February 16, 1976.
                   A sample of the file is given in Appendix
                   B-1; this file follows the formats of
                   Table 2.1. It will be noticed that the
                   zones are listed in the same order as the
                   665 airports, including the arbitrary
                   zone 99 for the airport OUT. The 5,402
                   aircraft itineraries are comprised of
                   38,222 events. Since each flight leg
                   comprises one departure event and one
                   arrival event, the file has 19,111 flight
                   legs. All flights listed in the OAG for
                   the given date that have one or more events
                   at the listed airports are included in the
                   ANFS.DAT file. Creation of the ANFS.DAT

C-5

XTRACT.F4

file for a different day is possible by re-running the programs employed to create it.

This FORTRAN program performs the function described in Section 2.1.4 of this report, i.e., it extracts from ANFS.DAT only those flights that go to, from, or through the airport specified at the user's TTY. This airport input is labelled (2) in Figure C-1.

FLIGHT.DAT

The output of XTRACT.F4, labelled in Figure 1 as (3), is stored in the file FLIGHT. DAT. It has the same format as ANFS.DAT, but is usually much shorter. The first airport in the APT and ZONE lists, more-over, is the airport that the user has inputted to XTRACT.F4 from his TTY, and is the airport for which the extraction was performed.

ANFS.F4

The ANFS.F4 is the simulator itself, and is described extensively in Section 3. of this report. A listing is given in Appendix B-4.

ANFS.OUT

The output of the simulator is described in Section 4. of this report. A sample for JFK is given in Appendix B-5.

COST.DAT

This file provides cost, passenger load, and airline and equipment information needed in ANFS.F4 to calculate the cost of delays. It is described more fully in Section 2.3 of this report. A sample of COST.DAT is not given, because it is redundant with the FORTRAN program COST. F4 that generates it.

COST.F4   This program generates COST.DAT, the
cost data file used by ANFS.F4. It is
decribed in Section 2.3 of this report,
and a listing is given in Appendix B-3.
The cost and related data are contained
in DATA statements of the program. It
is necessary to modify these data state-
ments to alter costs, loads, etc.

CAPCTY.DAT   The processing rates, non-scheduled traffic
percentage, and non-scheduled traffic
hourly pattern are stored in this data
file. The format and exact definition
of the data are given in Section 2.2 of
this report. A sample of CAPCTY.DAT is
given in Appendix B-2.

In order to run the simulator, the user should first
compile and run XTRACT.F4, entering at the TTY the three-letter
code of the airport for which he wishes itineraries extracted.
This will produce the proper FLIGHT.DAT file, with the specified
airport first on the APT and ZONE lists. Next, the user should
create the proper CAPCTY.DAT file. It is recommended that he
specify capacity for the airport for which the FLIGHT.DAT file was
created, and follow this immediately by the airport ALL showing
ϕ for service intervals and non-scheduled traffic. This will
allow landing and takeoff delays only at the extracted airport,
and B-delays at airports connected to it by traffic.

Finally, the user may compile and run ANFS.F4. It is not
necessary to regenerate the COST.DAT file unless the cost data in
COST.F4 has been changed.

If it is desired to make a test run, the user should create
the FLIGHT.DAT file for John F. Kennedy airport by entering JFK
at the TTY when running XTRACT.F4. If the COST.DAT file is that
given in Appendix B-3., and if the CAPCTY.DAT is that given in
Appendix B-2., second page, then compiling and running ANFS.F4 will
yield the output given in Appendix B-5.

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